H Belkin

FLUID INCLUSION RESEARCH

Edwin Roedder, *Editor*
Andrzej Kozlowski and Harvey E. Belkin,
Associate Editors

Volume 22
1989

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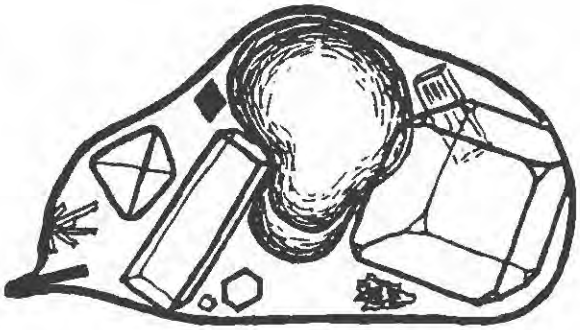

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PREFACE

The purpose of these volumes is to provide entrée into the world literature for the year with English abstracts or annotated citations of all items that either contain fluid inclusion data or are pertinent to some aspect of fluid inclusion work. This covers all types of fluid inclusions (aqueous, organic, silicate melt, sulfide melt, gas, etc.), causes and mechanisms of trapping (including various types of immiscibility), physical, chemical, and isotopic data, and data on experimental studies of systems pertinent to the interpretation of all types of phase changes occurring in inclusions, as well as to the sources and movement of such volatiles or fluids and their interactions with rocks. These data are generally given without editorial value judgments except in the case of obviously contradictory or obscure statements, where comments or "sic" are added in brackets. The extent of coverage varies in part as an inverse function of the availability of the original text to the average Western reader and in part as a direct function of the usefulness of the data. Items that are difficult to obtain, such as theses, may be covered in more detail than scientifically more important publications from readily available journals. Pertinent past and future meetings, and the resulting publications, are also listed.

This volume contains 1396 abstracts, citations, or annotated citations total, including 108 from the Russian, 37 from the Chinese, 85 from 12 other languages, and 30 from theses. Translations of titles and abstracts were provided by N. Berdnikov (Khabarovsk, USSR); D.A. Brown (Canberra, Australia); J. Dubessy (Nancy, France); C.J. Eastoe (Tucson, AZ); S.N. Grishina (Novosibirsk, USSR); S. Jaireth (Townsville, Australia); I.V. Kulikov (Moscow, USSR); G. Landis (Denver, CO); P. Lattanzi (Firenze, Italy); H.-Z. Lu (Chicoutimi, Québec); R.P. Moritz (Sainte-Foy, Québec); R.M. Prol-Ledesma (Mexico City, DF); G. Ruggeri (Firenze, Italy); Y. Seki (Tsukuba, Japan); H.A. Stalder (Bern, Switzerland); T.M. Suschevskaya (Moscow, USSR); S. Taguchi (Fukuoka, Japan); and S. Takenouchi (Tokyo, Japan); and, of course, Associate Editor Kozlowski. Translations of full articles were obtained from C.G. Cunningham (Reston, VA); S. Grishina (Novosibirsk, USSR); and Kozlowski. Chemical Abstracts, of Columbus, Ohio, has most graciously permitted the use of a few of their copyrighted abstracts, as indicated by a CA number at the end of the abstract. Other help has also been received from: C.E. Barker (Denver, CO); M. Fleischer (Smithsonian Institution, Washington, DC); A. Gize (Manchester, UK); J. Guha (Chicoutimi, Québec); B.E. Nesbitt (Edmonton, Alberta); R. Thomas (Potsdam, GDR); and most particularly from J. Hedenquist (Tsukuba, Japan). Many other individuals, too numerous to list here, have helped by sending books, reprints, references, and abstracts. I am deeply indebted to my coeditors Kozlowski and Belkin for their hard work, and to the U.S. Geological Survey and Harvard University for their cooperation. I also want to thank Kathleen R. Roedder for the locality index and Nancy Teed (USGS) and Margie Sentelle (VPI&SU) for the excellent typography.

Some cited items came from various computer searches but could not be looked up in time; they may involve only a trivial mention of fluid inclusions or they may be major items, since such distinctions are not normally made in computer databases. Although computerized bibliographic searching seems to be the obvious wave of the future, and it is indeed marvelous to sit at a terminal and watch it spew out references galore, some serious reservations remain. *First*, it is necessary that the desired items be *in* the database. Although several extensive geological literature computer databases have been consulted here, each such search nets only a few items not previously found, but most important, each produces only a *small fraction* of the entries present in any given volume of Fluid Inclusion Research. *Second*, and most important for a subject such as fluid inclusions, the data must be retrievable by applicable subject searches. A database is only as good as the indexing that went into the entries, and herein lies the problem. One needs only to make various trial subject searches of a computer database that *should* pull out items from his own personal bibliography to realize how inadequate this indexing of geological databases has been in the past.

To authors of pertinent articles that have been omitted or are misquoted here through haste, or through language difficulties, I extend my apologies and my request to have these things called to my attention; to authors whose original abstracts have been drastically shortened, edited, or revised, I offer a reminder that the following "abstracts" are not intended to be abstracts of the whole paper, but only that part most pertinent to inclusion workers. The obvious inconsistencies in citation, transliteration, abstracting, editing, cross-referencing, and indexing are strictly a result of lack of editorial time. A necessary consequence of the recent accelerated publication schedule for these volumes is an increase in the number of items in any volume from the previous year, simply because they were not available before the necessary editorial cutoff.

I will be glad to learn of unpublished translations of foreign language inclusion literature, and will also be glad to furnish photocopies of the original text of articles or abstracts that have not been translated, or back issues of Fluid Inclusion Research, in exchange for partial or full translations for use in future issues. I would particularly like to receive abstracts from pertinent graduate theses and dissertations, as these are exceedingly difficult to locate.

July 1991 Edwin Roedder, Editor

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SUBSCRIPTION INFORMATION

Volume 22 (1989), $20.00; back issues (if in stock) or photocopies of back issues, $6.00/volume; all post-paid if payment received in advance. Standing subscription orders receive 20% discount (e.g., Volume 22—$16.00). All subscription correspondence and checks (made out to "Fluid Inclusion Research" in U.S. dollars and drawn on a U.S. bank) should be sent to:

Fluid Inclusion Research Business Manager
Department of Geological Sciences
VPI & SU, Blacksburg, VA 24061, U.S.A.
Phone (703) 231-7455 or (703) 231-6521
Fax (703) 231-3386

All correspondence concerning editorial matters, and particularly offers of help on abstracting or translation, should be addressed to the Editor:

Edwin Roedder, Editor
Fluid Inclusion Research
Department Earth and Planetary Sciences
Harvard University, Cambridge, MA 02138, U.S.A.

VOLUNTEERS NEEDED

The editors would appreciate any help that can be offered by the readers in issuing future volumes of Fluid Inclusion Research. Help is particularly needed in translation and in preparing abstracts on a *regular* basis from various segments of the literature. These jobs can be partitioned into as small units as desired; please contact any one of the editors at the following addresses. On an informal basis, it would be most helpful if readers could send to the editors reprints or even just reference citations of pertinent literature. Such help is particularly useful to avoid missing obscure publications, such as theses, or ones in which the presence of inclusion data may not be obvious from title or abstract. If important papers have been missed in previous volumes, they also should be noted.

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EDITOR'S SPECIAL REQUEST TO USERS

In the front of Volume 21, I printed the following request; since then I have received only a few responses from the readers. I would greatly appreciate more feedback.

A lot of volunteers have put a lot of time into Fluid Inclusion Research. Perhaps it is now appropriate to step back and examine this publication to see whether it is achieving its goal, whether it should change in any way, or, for that matter, whether it should even continue in the future. Such questions can be answered *only* if you, the users, let us know your feelings. As its preparation is a volunteer operation and its printing is a non-profit operation, I cannot promise gross changes that will increase the load. But I believe I can speak for the whole crew when I say we want to make it useful, and hence ***we need your input.***

We are working on major revisions in the indexing procedures. We are also contemplating putting all past (and future) Fluid Inclusion Research citations into a computerized file so that searches could be made by keyword or author. You can help us make these planned actions as useful as possible **by telling us what index entries and/or keywords would be most useful *to you***, and also what would be your computer hardware/software requirements or limitations.

July 1991

Edwin Roedder, Editor
Department of Earth and Planetary Sciences
Harvard University, Cambridge, MA 02138, USA

NOTICES OF MEETINGS AND SYMPOSIA

Past Meetings

The 4th session of the N. Caucasian Division of the All-Union Mineralogical Society [USSR] was held at Terskol, April 1988, with 71 papers on mineral formation from boiling solutions. A volume of abstracts has been obtained (see Sedletskiy, 1988), and part will be found in this issue.

The 2nd Biennial Pan American Conference on Research on Fluid Inclusions (PACROFI II) was held in Blacksburg, Virginia, January 4-7, 1989. The Program and Abstracts Volume (74 pp.) is available postpaid, for $10.00 (US), to Fluid Inclusion Research Business Manager, Dept. Geological Sciences, VPI & SU, Blacksburg, VA 24061, USA. Twenty papers from this meeting were published in Geochim. Cosmochim. Acta, v. 54, no. 3, 1990 (224 pp.) and are also available for $15.00 as a special publication, "Recent research on fluid inclusions: PACROFI II." Make check payable to Pergamon Press, Inc., and send to G.C.A., Room 71, Pressey Hall, 1070 Carmack Road, The Ohio State Univ., Columbus, OH 43210, USA.

ECROFI X, the 10th meeting on European Current Research on Fluid Inclusions, was held at Imperial College, London, April 6-8, 1989. The Abstracts Volume for this meeting (101 pp.) is available for $20.00 (US) from the Mineralogical Society, 41 Queen's Gate, London SW7 5HR, UK. A special issue of Mineralogical Magazine, consisting of 18 papers from ECROFI X, is available for $40.00 (US) from the same address.

The 28th Int'l Geological Congress met in Washington, D.C., July 9-19, 1989. Abstracts of pertinent items are present in this volume.

A symposium on fluid inclusion research was held at the November, 1989, Geological Society of America meeting in St Louis, Missouri. Abstracts of the 23 presentations, plus the many other papers involving fluid inclusions, are present in this volume.

The 3rd Biennial Pan American Conference on Fluid Inclusions (PACROFI III) was held in Toronto, Canada, May 20-23, 1990, with 82 papers and posters presented. The Program and Abstracts Volume (98 pp.) is available postpaid for $20.00 (Can.) from Dept. Geology, Univ. Toronto, Ontario M5S 3B1, Canada. A group of papers presented at this meeting is to be published in Geochimica et Cosmochimica Acta, about October 1991, and will be available as a special publication (225 pp.)

The 15th General Meeting of the Int'l Mineralogical Association was held July 12-17, 1990, in Beijing, China. A symposium on fluid inclusions was on the program. Abstracts from this symposium, plus the many other papers involving fluid inclusions, are present in this volume. At the meeting Dr. B. De Vivo of Italy was elected chairman and Dr. Kalman Torok of Hungary was elected secretary of the working group on fluid inclusions.

The 8th Int'l Association on the Genesis of Ore Deposits Symposium (IAGOD) was held August 12-18, 1990, in Ottawa, Ontario, Canada. There were several sessions on fluid inclusions, under the sponsorship of the Commission on Ore-Forming Fluids in Inclusions (COFFI), with 19 papers. At this meeting R.J. Bodnar of VPI & SU was elected chairman of COFFI.

The Second Fluid-Infotroffen was held at Göttingen, FRG, August 28-30, 1990, under the aegis of the Inst. f. Geol. u. Dynam. der Lithosphare. Thirty-nine papers were presented (mostly in German) by 50 workers from six countries, covering a wide range of inclusion subjects. No abstracts were printed.

FLUIMUS '91, a symposium presenting the activities of the Fluid Inclusion Working Group (FLUIMUS) of the Mineralogical Society of South Africa (MINSA), was held Febuary 4, 1991, in Johannesburg, S.A., with 11 papers presented. Abstracts were not available for distribution.

A group has been organized in Japan for inclusion studies in geothermal fields, by Prof. S. Taguchi, Geol. Laboratory, Faculty of Science, Fukuoka Univ., 8-19-1 Nanakuma, Jonan-ku, Fukuoka-shi, 814-01, Japan. A 38-page booklet of short papers, in Japanese with English titles, includes such items as available equipment and a 12-page discussion of calibration procedures and standard substances, notices of meetings, and bibliography of pertinent papers.

The 6th meeting of the European Union of Geosciences, EUG VI, was held March 24-28, 1991, in Strasbourg.

ECROFI XI, European Current Research on Fluid Inclusions, took place in Firenze, Italy, April 10-12, 1991. There were 167 presentations (verbal and poster). The abstracts were printed in Plinius, Supplemento italiano all' European Journal of Mineralogy, Number 5, April 1991 (267 pp.)

Brazil Gold '91 was held May 13-17, 1991, in Belo Horizonte, MG, Brazil.

The joint GAC/MAC/SEG meeting, May 27-29, 1991, in Toronto had a special session on gems and gem deposits.

The Gemological Institute of America hosted an international gemological symposium, June 20-24, 1991, in Los Angeles, California.

Future Meetings

The Society for Luminescent Microscopy and Spectroscopy (SLMS) has been organized (formerly called the Society of Cathodoluminescence and Ultraviolet Microscopists) and has started issuing a newsletter (vol. 2, no. 1, was Spring 1990) that includes excellent color reproductions of cathodoluminescence views, and news of interest to anyone using this technique. Contact Dr. Otto C. Kopp, Dept. Geological Sciences, Univ. Tennessee, Knoxville, TN 37996-1410, USA; phone (615) 974-2366.

A meeting on source, transport, and deposition of metals, the SGA 25th Anniversary meeting, will be held August 30-September 3, 1991, in Nancy, France. Contact SGA Anniversary Meeting, CREGU, BP 23, 54501 Vandoeuvre-lès-Nancy Cedex, France.

An international conference on applied mineralogy will be held in Pretoria, S.A., September 2-4, 1991. Contact CSIR Conf. Coordinators (C. 133), P.O. Box 395, Pretoria, 0001, South Africa.

An international symposium on low-temperature metamorphic processes will be held November 8-20, 1991, in Auckland, New Zealand. Convenors are P. R. L. Browne and S. F. Simmons, Geothermal Institute, Univ. Auckland, Private Bag, Auckland, New Zealand; FAX 64-9-3071183.

PACROFI IV, Pan-American Current Research on Fluid Inclusions, will take place at Lake Arrowhead, California, May 22-24, 1992. Contact Dr. M. A. McKibben, Dept. Earth Sciences-036, Univ. California, Riverside, CA 92521-0423; phone (714) 787-3444.

The 7th Int'l Symposium on Water-Rock Interaction (WRI-7), with many sessions of interest to inclusionists, will be held July 13-22, 1992, in Park City, Utah. Preregistration deadline is April 1, 1991; contact Dr. Yousif Kharaka, Secretary General WRI-7, U. S. Geological Survey, MS 427, 345 Middlefield Road, Menlo Park, CA 94025.

The 29th Int'l Geological Congress will be held August 24-September 3, 1992, in Kyoto, Japan.

ECROFI XII, European Current Research on Fluid Inclusions, is tentatively scheduled for late Spring, 1993, in Poland. For information contact Dr. A. Kozlowski, Inst. Geochemii, Univ. Warszawski, 02-089 Warszawa, al Zwirki i Wigury 93, Poland.

REGIONAL REPRESENTATIVES

The following series of Regional Representatives have been established to provide foci for coordination and exchange of information on inclusion activities, and to help assure complete coverage of the world literature by forwarding reprints or citations to the editors.

Australia: Dr. Ronald W.T. Wilkins, CSIRO, Minerals Research Laboratories, P.O. Box 136, North Ryde, NSW 2113, Australia

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F.R.G.: Dr. Elfrun E. Horn, Inst. für Geol. u. Dynamik der Lith. der Georg-August-Univ., 3400 Göttingen, Goldschmidtstr. 2, FRG

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ABBREVIATIONS

The Cryillic sequence, , is converted to abcdef. Other than the normal scientific and reference abbreviations, we use mainly the following:

dm	daughter mineral	S	secondary
dxl	daughter crystal	T	temperature (°C)
dp	daughter phase	Td	temperature of decrepitation*
I	inclusion	Te	temperature of eutectic melting*
FI	fluid inclusion	Th	temperature of homogenization*
G	gas	Tm	temperature of melting*
L	liquid	Tn	temperature of nucleation*
V	vapor	Tt	temperature of trapping*
P	primary	(...)	part of the author's abstract omitted
PS	pseudosecondary	eq.	equivalent

*For explanation, please see next page. Some papers use "Tf" for "temperature of formation" (i.e., Tt), some use it as equivalent to Th, others use it for "temperature of freezing," meaning Tm ice (on heating), and still others mean Tn ice (on cooling). A few use "Te" for "temperature of crystallization," meaning either Tn (on cooling) or Tm (on heating).

The original author's usage has been followed on the following:

GLI	gas liquid inclusion	Ka	thousand years
HC	hydrocarbon	My	million (10^6) years
ppb	parts per billion (10^9)	Ma	million (10^6) years
ppm	parts per million (10^6)	mybp	million years before present
µg/g	parts per million (10^6)	Ga	billion (10^9) years
‰	parts per thousand	XCO_2	mole fraction CO_2
ppt	parts per thousand	K	temperature Kelvin
per mil	parts per thousand	mg	milligram (10^{-3} g)
per mille	parts per thousand	µg	microgram (10^{-6} g)
%	parts per hundred	ng	nanogram (10^{-9} g)
percent	parts per hundred	J	joule
Ky	thousand years	KJ	kilojoule

The original author's usage has also been followed on *pressure*. Most use bars (≈ atm ≈ kg/cm^2), kilobars (kb or kbar), or megabars (Mbar), but others use pascals: 1 kPa = 10^3 Pa = 0.01 bar; 1 MPa = 10^6 Pa = 10 bar; 1 GPa = 10^9 Pa = 10^4 bar = 10 kbar. Still others use N/m^2 for newtons per square meter (10^5 N/m^2 = 1 bar).

MICROTHERMOMETRY ABBREVIATIONS

A consensus of fluid inclusion workers on usage of microthermometric terms was reached and first printed in Volume 10 (1977). It is suggested that if this terminology is used consistently in future papers, considerable ambiguity will be avoided. The details have been reprinted in each succeeding volume, and hence will be given here only in summary. For ease of typewriting and typesetting, it is suggested that subscripts not be used (the possibility of confusion with element symbols is almost nonexistent). Note that these terms are *not* adequate to cover some of the complex phase changes in gas-rich inclusions (see Kerkhov, A.M. van den, 1989, in this volume).

Tt — The temperature of trapping, i.e., the temperature of formation of the inclusion. Thus Th = Tt if no pressure correction is needed.

Tf — The temperature of formation. Normally same as Tt.

Th — The temperature of homogenization. Unless otherwise indicated, this should refer to *total* homogenization. The phase into which homogenization occurs should also be stated as well (e.g., Th L or Th V). Where only the homogenization of a given pair of phases is meant, these should be designated, thus Th L-V, Th CO_2 L-V, etc. The phase into which such homogenization occurs should also be stated as well, thus Th CO_2 L-V (V), or Th H_2O-CO_2 (H_2O).

Tm — The temperature of melting. For ordinary water-rich inclusions, this may refer to the melting of ice, but ambiguity in this is all too common. The specific solid phase that melts (or dissolves) should *always* be designated. Thus Tm NaCl, Tm ice, Tm dms, Tm CO_2.

Te — The temperature of eutectic. This is the first *recognizable* formation of liquid on warming a completely crystalline inclusion; it is only an approximate or "practical" value at best, as traces of other components will always result in undectable traces of melting at lower temperatures.

Tn — The temperature of nucleation of a given phase. This generally refers to nucleation on cooling, normally from a supercooled, metastable fluid. Thus, Tn for an aqueous inclusion would be Tn ice, and formation of a bubble in a previously homogenized L-V inclusion would be Tn V.

Td — The temperature of decrepitation. This is used differently by various authors and cannot be defined exactly. Specific details on how such a temperature is determined, e.g., the start of decrepitation, the most rapid rise of decrepitation rate, the maximum number of impulses per unit increase in temperature, etc., will vary with the technique used and should be specified in each paper.

eq. wt % NaCl — That quantity of NaCl that would yield the same Tm ice value. Sometimes also used for a rough estimate, on NaCl dm-bearing inclusions, to signify total *apparent* NaCl content obtained by combining measurements of size (or Tm) of NaCl dm and an assumption as to NaCl concentration of solution at room temperature.

ABSTRACTS AND CITATIONS, 1989

Editorial Notes and Caveats

Some items from previous years that were not available earlier are included; there will be more of such back date items in this and future issues as a result of the faster publication schedule. Items for which a full English translation has become available during the year are included, even if the item was previously abstracted from the original foreign language. The first author's address is given as of the publication date only. Given names or only initial are listed as in the original. Differences in the transliteration procedures that are used in various Western journals for Cryillic author's or place names have resulted in different spellings of what is probably the same name (e.g., Petersil'e, Petersilie, and Petersilje; Ye vs E; ...iy vs ...ii, etc.). To avoid problems in the use of various bibliographic data bases, I have maintained such spellings *as they appeared in the original publications.* Similar problems occur with diacritic marks in author's names. (In alphabetizing here, these marks are ignored, except for the umlaut. Thus in alphabetizing here, ö follows o, etc. Note, however, that some journals delete all umlauts, and others delete the umlaut but add an "e" to the author's name (e.g., "ö" becomes "oe"), so the *same* author could appear at *three* different places in the following alphabetized listing.) Names starting with "van," "Van," "de," "De," etc., are alphabetized under V (or D), in part with a cross-reference entry under the family name, except when the author's preferences are known; names starting with "Mc" or "St" are alphabetized exactly as spelled. The differences in custom between Spanish and Portuguese peoples in the sequence of listing (and hence alphabetization) of double surnames presents possibilities for error in alphabetization. Even worse problems exist for Chinese names, which have been alphabetized here according to what I *believe* is the family name, regardless of the order of printing in the original.

Some special notes are needed about the many abstracts here from the 26th Int'l Geological Congress. A number of serious misprints were introduced in these abstracts during the making of the Abstracts volume, in author's names, titles, text, and even in complete omission of the abstracts of papers that were accepted and given verbally. When I had available the author's original versions, as submitted to the IGC, I have used these. Almost all IGC abstracts had to be shortened substantially here, references omitted, etc., due to space limitations. In editing, the meaning of some obscure passages had to be assumed; in others, where particularly obscure, I have quoted exactly and added [sic].

ABARJANO, T.A., Jr., STURCHIO, N.C., KENNEDY, B.M., LYON, G.L., MUEHLENBACHS, K. and **BOHLKE, J.K.**, 1989, Isotope geochemistry of fluids related to serpentinization of the Zambales ophiolite (Philippines) (abst.): Eos, v. 70, p. 1378.

We have determined O and H isotope ratios in serpentine and present-day meteoric water from the Zambales ophiolite, and carbon ($\delta^{13}C$, ^{14}C), H and noble gas isotope ratios in CH_4-H_2 gas seeps issuing presently from the ophiolite terrane. These data, together with geologic and petrologic observations, allow a comprehensive description of the chemical and isotopic mass balance involved in the serpentinization process.

δD and $\delta^{18}O$ values for serpentines are consistent with serpentinization by regional meteoric water. Noble gas isotope data, particularly for helium ($^3He/^4He \sim 4$ RA) and neon ($\delta^{20}Ne \sim 20‰$, $\delta^{21}Ne \sim 120‰$), and carbon isotope ratios ($\delta^{13}C \sim -7‰$) for the gas seeps indicate a contribution from a "mantle" component presumably derived from the mafic/ultramafic protolith of the serpentinite. However, $^{40}Ar^*/^4He$ (~0.8) also indicate addition of a significant crustal component. ^{14}C activity in CH_4 is <1 pmc, indicating an old carbon source. Geothermometric estimates based on serpentine-water O and H isotope exchange and on $\Delta D(CH_4$-$H_2)$ in the gas seep range from 30 to 200°C. The chemical and isotopic characteristics of minerals and fluids in the Zambales ophiolite indicate the prevalence of rock-dominated (water-deficient) conditions during serpentinization. (Authors' abstract)

ABERG, A. and **FALLICK, A.E.**, 1989, Gold-bearing quartz veins, Falun, Sweden; Preliminary results from fluid inclusions and oxygen isotopes (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 22. First author at Dept. Geology, Univ. Stockholm, S-106 91 Stockholm, Sweden.

The Falun mine, situated in the Proterozoic metallogenic province of Bergslagen in central Sweden, is one of the oldest mines still in operation. The dominant ore type in Falun is a complex sulphide ore, which was interpreted as an exhalative sedimentary deposit by Koark (1962). It is hosted by cordierite-bearing quartz rich rocks, which are interpreted as hydrothermally-altered volcanic (country) rocks. The Au deposit in Falun occurs east of the complex sulphide ore, with visible Au. The Au (electrum) occurs in quartz veins, associated with a wide range of Pb-Cu-Bi-selenides. Host rocks are the altered quartz-rich rocks.

Microthermometric measurements have been made on fluid inclusions in quartz from different positions in the vein system. Oxygen isotope composition has been analysed on six samples from the same position.

Two generations of veins have been recognized: (1) The veins of the early generation consist of clear quartz and high content of Au, selenides and sulphides. The quartz contains three types of inclusions. Type one: three-phase, CO_2-bearing inclusions giving Th of ~250-300°C. Type two: two-phase, aqueous inclusions with Th of 150-200°C. Type three: two-phase, S inclusions. Oxygen isotopic analyses on quartz give a mean $\delta^{18}O$ value of 5.8‰ (SMOW). This gives a calculated $\delta^{18}O$ value for the fluids: -4.2‰ (SMOW), using a weighted mean T of 220°C. (2) The veins of the later generation consist of milky quartz and lack Au and ore minerals. The quartz contains only type two and type three inclusions. Type two inclusions have given T of 100-200°C. Isotopic composition of quartz gives a $\delta^{18}O$ value of 7.1‰ (SMOW) and a calculated $\delta^{18}O_{fluid}$ = -7.6‰, using a T of 150°C. This indicates an evolution from hot CO_2- and Au-bearing solutions to cooler and barren fluids. The shift in oxygen isotopic composition could indicate that a mixture of seawater and meteoric water becomes more dominated by meteoric water with time. (Authors' abstract)

ABITZ, R.J., MYERS, Jonathan, DREZ, P.E. and DEAL, D.E., 1989, Geochemistry of Salado Formation brines recovered from the Waste Isolation Pilot Plant (WIPP) repository horizon (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A317.

ABLESIMOV, N.E., LIPATOV, V.G., TALTYKIN, Yu.V. and BERDNIKOV, N.V., 1988, The role of volatiles in generation of deep geophysical anomalies: J. Phys. Earth, v. 36, p. 191-196. Authors at Inst. Tectonics and Geophysics, Kim-Yu-Chen, 65 680037, Khabarovsk, U.S.S.R.

An analysis of the equations of state of volatile substances shows that the area of supercritical state corresponds to the P-T conditions of deep petrogenesis. Supercritical gases are solvents and therefore can play an important role in the formation of deep conductivity anomalies and probably of anomalies in other geophysical fields. (Authors' abstract)

AFZAL, M., SALEEM, M. and MAHMOOD, M.T., 1989, Temperature and concentration dependence of viscosity of aqueous electrolytes from 20 to 50°C. Chlorides of Na^+, K^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, and Cr^{3+}: J. Chem. Eng. Data, v. 34, p. 339-346.

AGTERBERG, F.P., 1989, Computer programs for mineral exploration: Science, v. 245, p. 76-81.

Includes a brief discussion of the PROSPECTOR network, for porphyry molybdenum deposits, which involves highly saline FI evidence as a favorable indicator. (E.R.)

AHMAD, Masood, 1989, Fluid inclusion study of greisens associated with the Nicholson Granite Complex, Murphy Inlier, Northern Territory: Australian J. Earth Sci., v. 36, p. 207-218. Author at Dept. Mines and Energy, Northern Territory Geol. Surv., P.O. Box 2901, Darwin, NT 5794, Australia.

The Early Proterozoic Nicholson Granite Complex contains Sn-W-bearing quartz-muscovite greisens as irregular pods and as tabular veins with both interstitial and vug-filled cassiterite and minor wolframite. Within the greisens, alteration to muscovite varies with the intensity of alteration from Fe-poor non-pleochroic through Fe-rich pleochroic to Fe-bearing pleochroic fibrous varieties. Because of accompanying silicification, a typical greisen contains about 20% muscovite and 75% quartz; other minerals include pyrite, chalcopyrite, hematite, fluorite, topaz and phlogopite.

Six kinds of FI are present in vein quartz within the greisens: Type A (L + <10% V); Type B (L + 10-30% V); Type C (V only or L + >80% V); Type D (L + halite + <10% V); Type E (L + halite); and Type F (L only).

Early "primary" I represented by Types B and C have higher T (range: 190-400°C, mean = 300°C) and lower salinities (range: 0.3-12 wt % eq. NaCl, mean = 6 wt % eq. NaCl) than the late PS I represented by types A, D and E (T range: 90-330°C, average 165°C, salinity range: 0.5-40 wt % eq. NaCl, mean = 24 wt % eq. NaCl). Coexisting V and L + V I in most samples indicate that solutions were boiling, which is substantiated by V phase homogenization of many I. The late high salinity-low T fluids were probably caused by extensive boiling.

In the early high T-low salinity fluids, Sn was predominantly transported as a stannous hydroxide complex and precipitation caused by an increase in oxidation and decrease in T, both of which are attributed to boiling. The late low T-high salinity fluids carried Sn predominantly as stannic hydroxide and precipitation was essentially due to lowering T.

Comparisons with other Sn-bearing granites suggest a crustal source for the Nicholson Granite Complex and associated Sn greisens. (Author's abstract)

AKANDE, O., ZENTELLI, M. and REYNOLDS, P.H., 1989, Fluid inclusion and stable isotope studies of Pb-Zn-fluorite-barite mineralization in the lower and middle Benue Trough, Nigeria: Mineral. Deposita, v. 24, no. 3, p. 183-191. First author at Dept. Geology and Mineral Sciences, Univ. Ilorin, P.M.B. 1515, Ilorin, Nigeria.

Pb-Zn-fluorite-barite veins in the lower and middle Benue Trough (Nigeria) are located within the Lower Cretaceous (Albian) carbonaceous shales, limestones, and arkosic sandstones of this intracontinental rift structure. The veins in the lower Benue Trough consist of sphalerite + galena + marcasite ± chalcopyrite ± barite in a gangue of siderite and quartz hosted by carbonaceous shales, whereas in the middle Benue Trough, fluorite, barite, quartz, and similar sulfide minerals are hosted by limestone and sandstone. FI T in vein minerals range from 95°C to 200°C (without P corrections) and salinities range from 14 to 24 eq. wt % NaCl. O isotope compositions of limestone wall rocks (middle Benue) have been lowered from premineralization $\delta^{18}O$ values of ~25‰ to ~16‰. Fluid in equilibrium with vein calcite has a calculated $\delta^{18}O$ of +2.6‰ at 130°C. The $^{87}Sr/^{86}Sr$ ratio of this calcite (0.71497) suggests that Sr and Ca had a considerably more radiogenic source than the Cretaceous limestone or evaporite did ($^{87}Sr/^{86}Sr = 0.7073$-0.7078). Observed Sr data, Pb isotope compositions of galena, and REE patterns in fluorite suggest that the Lower Paleozoic basement rocks in the trough or their weathered equivalents are likely sources for the Benue Trough ore components. S isotope data suggest that the S was probably contributed from the Cretaceous evaporites in the trough.

Our data favor a basinal brine source for the ore-forming fluid. Fluid circulation probably resulted from high geothermal gradients accompanying continental rifting. Brine interaction with the clastic, carbonate, and evaporite rocks led to metal and S leaching and later deposition in fractures accompanying the Cenomanian deformation and uplift in the Benue Trough. (Authors' abstract)

ALARCON, H. and VILLAPANDO, A., 1989, Hydrothermal alteration and thermometry of 'La Joya" gold-silver deposit, Oruro, Bolivia (abst.): Terra abstracts, v. 1, p. 7.

The altered rock shows Si, Al, Fe as major elements and K, when alunite and jarosite are present; Ca, Ti, Zr, as minor elements and Cu, Zn, As, Sb, Sn, Ag, Au, Pb and Mo as trace elements. Fine inclusions of native gold were observed included in jarosite, but also associated with quartz. The silver is probably related to jarosite as argento-jarosite. S fluid inclusions with Th from 275 to 400°C were observed in phenocrystals of quartz from the altered dacite at La Joya and 265 to 315°C at the Koricollo. (From authors' abstract by E.R.)

ALEKHIN, Yu.V., BYCHKOV, A.Yu, GRICHUK, D.V., KOSHEMCHUK, S.K. and MIGDISOV, A.A., 1988, Mechanism of formation of the ore-forming geochemical threshold in boiling hydrotherms of the caldera of Uzon (Kamchatka): Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 54-55 (in Russian). First author at Inst. Exper. Mineralogy of Acad. Sci. of USSR, Chernogolovka near Moscow, U.S.S.R.

A computer model of the presently active hydrothermal system. (A.K.)

ALTHAUS, E. and ISTRATE, G., 1989, Nitrogen-methane fluids in granulite facies rocks from Valle Strona/Ivrea zone, W. Alps: Their bearing on the evaluation of P-T conditions of formation (abst.): Berichte der

Deutschen Mineralog. Gesselschaft, no. 1, p. 7 (in English) (supplementary issue to European J. Mineral., v. 1.). Authors at Karlsruhe.

Fluid inclusions in matrix quartz grains and in quartz enclosed in garnet and feldspars show distinct distribution patterns consistent with several generations of inclusions.

High-density, early/*P fluid inclusions* containing N_2 and CH_4 are typical in the most characteristic granulitic facies rocks of Valle Strona (Ivrea Zone), i.e., garnet pyriclasites and felsic granulites/stronalites. Extremely low Th of the monophase fluid inclusions (with no visible water or clathrate formation) into the liquid phase (T_{HL}), in the range of -164 to -178°C indicate an essentially N_2-CH_4 fluid with a high density of 0.62 to 0.68 g/cm^3 (X_{N2} = 0.7). These inclusions are members of P small populations that survived later events in the rock evolution. A large majority of the inclusions were naturally decrepitated or leaked during the uplift and show lower fluid densities. The isochores for N_2-CH_4 mixtures (Swanenberg, Diss. Univ. Utrecht, 147 pp., 1980) in early, "granulitic" fluid inclusions yield a pressure range of about 7.5 to -9.5 kbar at granulite facies T of 700 to 820°C estimated by Schmid and Wood (Contrib. Min. Pet, 54, 255, 1976), depicting the entrapment of fluids present during or close to the peak metamorphic stage (Fig. 1).

A subsequent monophase type of inclusion records entrapment of *later, high-density "carbonic fluid"* that consists of CO_2-CH_4 mixtures (Tm = -61 to -63.7°C; T_{HL} = -17.2 to -32.8°C with $X_{CH4} \approx$ 0.25-0.45 and d = 0.85-0.95 g/cm^3 (Swanenberg, Contrib. Min. Pet., 68, 303-306, 1979). These fluids are probably connected with the anatectic processes affecting the granulites. The "equivalent CO_2"-isochores for the early, unaltered carbonic inclusions yield a P range of ~5.0-5.5 kbar, while the partially decrepitated cavities (T_{HL} = -5.4 to -17°C) indicate P of ~4.5 kbar.

A late generation of inclusions, containing essentially CO_2-H_2O with variable salinity occurring along rehealed microfractures in quartz, is connected with late Hercynic or Alpine stages and was formed during the retrograde evolution of the granulitic facies rocks.

The data presented suggest that the metamorphic fluids evolved from early, syn-granulitic, high-density N_2-CH_4 through mixed "carbonic" CO_2-CH_4(H_2O) anatectic(?) to late CO_2-H_2O dominated fluid. It may be supposed that many exploded cavities observed by De Negri and Touret (Mem. Sci. Geol., 33, 87-94, 1980) have been originally high-density N_2-CH_4 and CO_2-rich fluid inclusions that partially or totally lost their contents during the retrograde events.

In many respects the characteristic fluids of the Valle Strona granulitic facies rocks are similar to Calabria granulites (Istrate and Althaus, N. Jb. Miner. Mh., 3, 97-108, 1989), i.e., the important role played by N_2-CH_4 fluids during granulite metamorphism, the subordinate role of CO_2 and H_2O that are essentially introduced during a subsequent event including anatexis. It is documented once more that high-density fluid inclusions can survive later metamorphic evolution and uplift. The CO_2-streaming as a cause of granulitic facies metamorphism is probably not as universally present as presumed. (Authors' abstract)

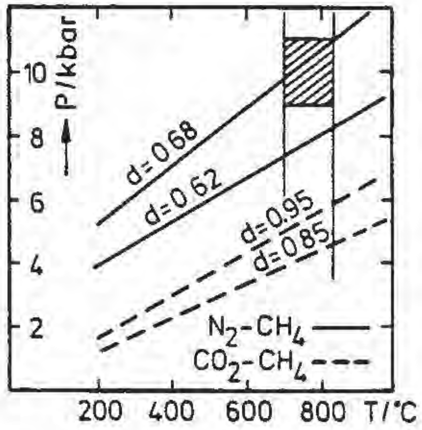

Figure 1. N_2-CH_4 and CO_2-CH_4 isochores and the P-T conditions of the granulite facies rocks, Valle Strona/Ivrea Zone (hatched area, after Schmid and Wood, Contrib. Min. Pet., 54, 255, 1976).

ALVAREZ, A.A., BONELLI, J.A. and **NOBLE, D.C.**, 1989, Sedimentary-rock-hosted precious-metal deposits of Yauricocha district, central Peru (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-37. First author at Centromin-Peru S.A., La Oroya, Peru.

Two types of bulk-mineable sedimentary-rock-hosted precious-metal deposits are found in the Yauricocha district, central Perú. The Purisima Concepción deposit is lithologically and chemically very similar to "Carlin-type" deposits of the western United States. The unusual Mascota deposit consists of highly oxidized and leached polymetallic ores containing subequal values of Au and Ag.

Ore deposits at Yauricocha are spatially and genetically related to a K-silicate altered late Miocene granodiorite stock. The principal ores are found in rich zoned pipe-shaped polymetallic (Cu-Zn-Pb-Ag-Au) limestone replacement ore bodies bordering the stock. The ore-depositing solutions initially had low pH and high fO_2 and fS_2, as shown by the rapid dissolution of carbonate wallrock, the essence [sic] of enargite, tetrahedrite, and high-S copper sulfide minerals, and the development of the assemblage quartz-pyrite-pyrophyllite-diaspore-alunite-anhydrite and high-T, compositionally complex high-salinity fluid inclusions near enargite veins in the stock. The magmatic-hydrothermal system may have been similar to that of Julcani and other enargite-tetrahedrite districts in Perú, with the difference in ore types largely reflecting the carbonate host at Yauricocha and position relative to the pluton. (From authors' abstract by E.R.)

ANDERSEN, T., AUSTRHEIM, H. and **BRIDGWATER, D.**, 1989, P-T and fluid evolution of the Angmagssalik "charnockite" complex, SE Greenland, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 71-94. First author at Mineralogisk-Geologisk Museum, Sarsgate 1, N-0562 Oslo 5, Norway.

The Angmagssalik "charnockite" complex is a belt of Proterozoic orthopyroxene-bearing metamorphic and igneous rocks situated within the central parts of the Nagssugtoqidian mobile belt of East Greenland. The oldest intrusive rock unit in the complex is a melagabbro, which may represent a pyroxene cumulate from a mafic melt. This unit is cross-cut by leuconorite (the most abundant unit in the complex) and by minor anorthosite and hypersthene veins. The country rock of the intrusives is an amphibolite facies quartzofeldspathic garnet gneiss, which has developed opx-bearing (granulite facies) mineral assemblages near the intrusive contact, and which has been physically mobilized and intermixed with the intrusives.

Quartz and plagioclase in melagabbro contain P and S pure CO_2 inclusions, with accidentally trapped solid silicate and carbonate crystals. These inclusions have Th(L) in the range 0 to -20°C. Pure CO_2 is also characteristic for inclusions in plagioclase in the leuconorite and in the anorthosite veins. The inclusions in leuconorite are distinctly S and have higher densities (Th ranging down to -30°C). S carbonic fluid inclusions in the country rock gneisses contain minor methane and range in Th from +10°C (garnet) to -10°C (quartz, plagioclase).

Combined with mineral thermobarometry on cpx-opx, gnt-opx and gnt-bi assemblages, the fluid inclusions data suggest an interpretation of the cooling history and fluid evolution of the complex: Primary magmatic rocks crystallized in the middle-lower crust (P: 6-8 kbar, T: 1000-1100°C). The higher density, S inclusions reflect isobaric cooling in the presence of CO_2 as a free fluid phase. This fluid phase migrated into the country-rock gneisses, where interaction between rocks and fluid led to the evolution of dry, granulite facies mineral assemblages. In this process, the CO_2 mixed with CH_4-bearing fluids or reacted with hydrous minerals to yield fluids with minor methane contents. (Authors' abstract)

ANDERSEN, T., AUSTRHEIM, H. and **BURKE, E.A.J.**, 1989, Fluid inclusions in granulites and eclogites from the Bergen Arcs, Caledonides of W. Norway (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 1. First author at Mineral.-Geol. Museum, Univ. Oslo, N-0562, Oslo 5, Norway.

The Grenvillian granulite-facies complex on Holsnoy island, Bergen Arcs, W. Norway, have been metamorphosed at eclogite-facies conditions during the Caledonian orogeny (ca. 425 Ma). The granulite-eclogite facies transition takes place along shear zones and fluid pathways. Mineral thermobarometry indicates PT conditions of 800-900°C, 8-10 kb for the Proterozoic granulite facies metamorphism and 700-800°C, 16-19 kb for the eclogite forming event (Austrheim and Griffin, 1985, Chem. Geol., 50, 267). Quartz in the granulite facies complex contains FI dominated by CO_2, with molar volumes compatible with the PT conditions of the Proterozoic granulite metamorphism. Quartz in pegmatitic quartz + omphacite and quartz + phengite/paragonite veins coeval with shear-zone eclogites contain $N_2 + CO_2$ FI. Combined laser-Raman microanalysis and microthermometry shows that the least disturbed of these inclusions have $X(CO_2) = 0.1\text{-}0.2$, and molar volumes less than 40 cm^3/mole, which may agree with the PT conditions during Caledonian high P metamorphism. Later, low density N_2 and N_2-H_2O FI have been influenced by processes during the retrograde PT evolution of the eclogites. (Authors' abstract)

ANDERSEN, T., BURKE, E.A.J. and AUSTRHEIM, H., 1989, Nitrogen-bearing, aqueous fluid inclusions in some eclogites from the Western Gneiss Region of the Norwegian Caledonides: Contrib. Mineral. Petrol., v. 103, p. 153-165. First author at Mineralogisk-geologisk museum, Sars gate 1, N-0562 Oslo 5, Norway.

Minerals in eclogites from different localities in the Western Gneiss Region of the Norwegian Caledonides (age $\approx$425 Ma) contain a variety of fluid inclusions. The earliest inclusions recognized are contained in undeformed quartz grains, protected by garnet, and consist of $H_2O + N_2$ (with $XH_2O \geq 0.8$). The reconstructed P-V-T-X properties of these fluid inclusions are compatible with peak or early-retrograde metamorphic conditions. Matrix minerals (quartz, garnet, apatite, plagioclase) contain a complex pattern of mostly truly S inclusions, dominated by CO_2 and N_2. The textural patterns and P-V-T-X properties of these inclusions are incompatible with the high P of the eclogite-forming metamorphic event, but suggest that they were formed during uplift, by a combination of remobilization of preexisting inclusions and influx of external fluids. The fluid introduced at a late stage was dominated by CO_2, and did not contain N_2. The present data agree with theoretical predictions of eclogite fluids from mineral equilibria, and highlight the differences between granulite (CO_2) and eclogite ($H_2O + N_2$) fluid regimes. The provenance of the N_2 in the eclogite fluid inclusions represents an important but unsolved question in the petrology of high-P metamorphic rocks. (Authors' abstract)

ANDERSON, A.J., CLARK, A.H., XIN-PEI, Ma, PALMER, G.R., MacARTHUR, J.D. and **ROEDDER, Edwin,** 1989, Proton-induced X-ray and gamma-ray emission analysis by unopened fluid inclusions: Econ. Geol., v. 84, p. 924-939. First author at Dept. Geological Sciences, Queen's Univ., Kingston, Ontario K7L 3N6, Canada.

An external beam (avg diam 20 µm) of protons from a 4.0-MV Van de Graaff accelerator has been used to excite, simultaneously, characteristic X-rays and gamma rays from a wide range of elements contained in individual, unopened, fluid inclusions in doubly polished mineral plates. We report qualitative and semiquantitative compositional data obtained using the proton-induced X-ray (PIXE) and gamma-ray (PIGE) emission techniques for selected, near-surface (10-40 µm deep) inclusions from three major, well-studied ore deposits.

Proton-induced X-ray emission analysis of numerous low-salinity, CO_2-bearing inclusions in quartz from the Panasqueira wolframite-quartz vein system, Portugal, did not detect Na, Cl, or K, presumably because of X-ray attenuation, whereas proton-induced gamma-ray emission analysis revealed Na in all inclusions. The gamma-ray spectrum yielded by an inclusion containing a dxl or accidentally trapped crystal resembling muscovite confirmed the presence of F, Na, and Al; and several X-ray spectra recorded K, Ti, Mn, Fe, Cu, Zn, Rb, and Sn.

Proton-induced X-ray emission analyses of multiphase fluid inclusions in quartz from a molybdenite-rich veinlet in the core of the Bingham, Utah, porphyry Cu(-Mo) deposit confirmed the presence of the S, Ca, Cl, K, and Fe, expected from the occurrence of anhydrite, sylvite, and hematite dxls. Quantification of the abundances of the lighter elements was subject to considerable error, but the data permit reasonable estimates of several heavier elements: Mn, 1,700; Fe, 28,000; Cu, 700; Zn, 1,800; Pb, 700; and Br, 200 (all in ppm).

Two fluid inclusions were examined in secondary spodumene from the Tanco, Manitoba, rare element pegmatite; both contained a highly birefringent dxl initially assumed to be the new mineral diomignite ($Li_2B_4O_7$). The proton-induced gamma-ray emission spectra were compared to those obtained from $Li_2B_4O_7$ sealed within SiO_2 glass capillaries. Boron was clearly detected in the capillaries but not in two large dxl, one of which contains major amounts of Ca (tens of wt %) and is tentatively identified as calcite.

Although these data are preliminary and mainly qualitative, they demonstrate that the combined proton-induced X-ray and gamma-ray emission method has great potential for fluid inclusion studies. Considerable improvements in instrumentation and techniques for fluid inclusion analysis are anticipated, as are more accurate determinations through precise standardization employing synthetic inclusions of known composition. (Authors' abstract)

ANDERSON, A.T., Jr., 1989, Volcanic outgassing inferred from melt inclusions (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-41. Author at Univ. Chicago, Chicago, IL.

Due to the pioneering work of Stolper and others on the spectroscopic determination of H_2O and CO_2 in silicate melts, it is now possible to analyze melt inclusions for these volatiles with 1-10% accuracy. This analytical capability coupled with petrographic study opens the way to determine the crystallization depth and outgassing behavior of bodies of magma beneath volcanoes. Anderson et al. (in press; Geology) present evidence for gas saturation in the rhyolitic magma that erupted to form the Bishop tuff, California. Unpublished spectroscopic work on melt inclusions in Hawaii olivines is consistent with earlier evidence from fluid inclusions that Kilauean and Mauna Loa basaltic magmas are saturated with a CO_2-rich gas to depths of many kilometers. Given gas saturation of volcanic magmas, it is possible to estimate the mass fraction of gas present in crystallizing magma at various depths from the variation in the dissolved H_2O/CO_2 with crystallization. This can be realized qualitatively from the fact that a system with a very large mass fraction of gas is buffered with respect to H_2O/CO_2, whereas one with a negligible mass fraction of gas will preferentially transfer the least soluble volatile (CO_2) into the gas with crystallization of volatile-free solids. Both the P and the mass fraction of gas present can be expressed algebraically in terms of solubilities and measured concentrations. The mass fraction of gas lost or accumulated can be inferred as a function of P. Adjustments will be necessary if SO_2 and other species are significant. The volume fraction and origin (shrinkage, crystallization, or initial entrapment) of bubbles of gas in melt inclusions must be determined. In addition, other within-inclusion, post-entrapment redistributions of volatiles need to be evaluated by analyzing different parts of inclusions or by heating and homogenizing inclusions before analysis. The latter has been done successfully by Peterson and Skirius (unpublished) in gas P experimental apparatus for rhyolitic inclusions in quartz. For rhyolitic inclusions, it appears that the presence of single bubbles of gas within rapidly cooled (e.g., Plinian) inclusions of glass signals probable pre-eruptive cooling of magma associated with its ascent into a low-P body. It may be possible to determine the initial volatile content (gas + dissolved in melt) of some magmas and thereby to establish whether some source regions are gas-saturated. (Authors' abstract)

ANDERSON, A.T., Jr., NEWMAN, Sally, WILLIAMS, S.N., DRUITT, T.H., SKIRIUS, Christine and STOLPER, Edward, 1989, H_2O, CO_2, Cl, and gas in Plinian and ash-flow Bishop rhyolite: Geology, v. 17, p. 221-225. First author at Dept. Geophys. Sci., Univ. Chicago, 5734 S. Ellis Ave., Chicago, IL 60637.

Infrared spectroscopic (H_2O and CO_2) and electron microprobe (Cl) analyses of glass inclusions in Plinian and ash-flow quartz phenocrysts from the Bishop Tuff reveal the preeruption concentrations of volatiles in separate parts of the body of magma. There is an inverse relation between H_2O and CO_2 that can be explained (1) by closed-system, gas-saturated crystallization of parent magma to yield Plinian magma + (lost) crystals or (2) by the rise of CO_2-rich bubbles through water-rich magma. Our estimated P of gas-saturation range from about 1.6 kbar (Plinian) to 2.3 kbar (ash flow) and accord with geologic evidence for 3 km of magma withdrawal and caldera subsidence. (Authors' abstract)

ANDERSON, A.T., Jr. and **SKIRIUS, C.M.,** 1989, Preeruptive CO_2 in Kilauean glass inclusions (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 6.

Inclusions of glass in phenocrysts of olivine that were erupted and collected in 1959 from Kilauea Iki have been spectroscopically analysed for CO_2 and H_2O. CO_2 is present as CO_3^{-2} groups. Four inclusions in four crystals erupted on November 18 have 0.08, 0.02, 0.02 and <0.01 wt % CO_2. Two inclusions erupted on November 21 have <0.01 wt % CO_2. Large gas bubbles occur in two of the inclusions analysed and are common in other inclusions indicating that the melts were gas saturated. The low concentrations of CO_2 in all but one of the melt inclusions indicate that the inclusions formed within or above the level of Kilauea's summit reservoir of magma and after parental CO_2 had effervesced from the melt, consistent with current concepts of Kilauea's outgassing behavior deduced from volcanological studies. P CO_2-rich gas bubbles in olivines from Kilauea, Mauna Loa and Loihi documented by Roedder indicate that concentrations of CO_2 as great as ~0.2 wt % may be expected in melt inclusions formed from CO_2 saturated magmas beneath Hawaii. published volcanological estimates of parental CO_2 are as high as 0.6 wt % and suggest that even greater concentrations might be encountered, but these have not yet been found. The later erupted inclusions have significantly greater H_2O. The concentrations of H_2O that we have measured in inclusions are substantially larger than values reported for submarine basaltic glasses from Kilauea's east rift. These results, although fragmentary, suggest that the 1959 picritic eruption of Kilauea sampled some magma that had not completely equilibrated with the low P in the summit reservoir. Submarine Kilauean lavas, on the other hand, may generally have first equilibrated in a near surface body of magma and subsequently migrated down rift to higher P vents as suggested by volcanological studies. (Authors' abstract)

ANDERSON, A.T., Jr., SKIRIUS, C.M., LU, Fangqiong and DAVIS, A.M., 1989, Preeruption gas content of Bishop Plinian rhyolitic magma (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A270. Authors at Dept. Geophysical Sciences, Univ. Chicago, Chicago, IL 60637.

Six large inclusions of glass from five lumps of pumice have been analyzed for volatile and non-volatile elements by infrared spectroscopy and ion microprobe. Four of the pumice lumps come from stratigraphic levels within the Plinian deposit, and the fifth comes from the immediately overlying early ash-flow deposit that was shown to be closely related to the Plinian material (Hildreth, 1979, GSA Special Paper 180, 43-75). The ash-flow inclusion and three of the Plinian inclusions have CO_2 and H_2O concentrations consistent with a common entrapment P of 1.65 kbar. All six inclusions display a tight negative correlation between CO_2 and U.

The negative correlation between CO_2 and U indicates that the Plinian magma was gas-saturated. With crystallization the concentration of incompatible U increased in the liquid and CO_2 preferentially entered the gas thereby depleting the liquid in CO_2 relative to H_2O. The U-CO_2 correlation can be interpreted quantitatively to yield the mass fraction of gas present in the crystallizing Plinian magma. If the least differentiated liquid (corresponding to the ash-flow inclusion) is taken to represent a crystal-free parental liquid, then the derived liquids represented by the other inclusions evolved in a magma that began with 1.0 ± 0.3 wt % gas. The initial gas contained ~37 wt % CO_2. The CO_2 content of the gas decreased to ~16 wt % as crystallization increased the concentration of U in the residual liquid by a factor of ~1.5 and forced a higher proportion of H_2O into the gas. The most differentiated magma contained ~2 wt % gas and 33 wt % crystals. If crystals were present in the initial magma, these figures change to keep the same ratios of gas to liquid. The small amounts of U and CO_2 that enter crystals are neglected. A gas content of 1.0 wt % corresponds to 4.6 vol %. Conceivably, the preeruptive content of gas in the Plinian magma predisposed it toward the Plinian eruptive style. (Authors' abstract)

ANDERSON, G.M., 1989, Organic maturation and the origin of MVT deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A4.

ANDES, J.P., Jr., 1987, Mineralogic and fluid inclusion study of ore-mineralized fractures in Drillhole State 2-14, Salton Sea Scientific Drilling Project, California, U.S.A.: MS thesis, Univ. California, Riverside, CA.

See Andes and McKibben, 1987, Fluid Inclusion Research, v. 20, p. 9-10. (E.R.)

ANDREW, A.S., HEINRICH, C.A., WILKINS, R.W.T. and PATTERSON, D.J., 1989, Sulfur isotope systematics of copper ore formation at Mount Isa, Australia: Econ. Geol., v. 84, p. 1614-1626. First author at CSIRO Div. Exploration Geoscience, P.O. Box 136, North Ryde, New South Wales 2113, Australia.

The Cu ores at Mount Isa (Queensland, Australia) are hosted by the Urquhart Shale, a metamorphosed Proterozoic sequence of dolomitic siltstones and shales. Sulfur isotope data from Cu ores and their hosts suggest that the highly pyritic Urquhart Shale provided a major sulfur component to the Cu ores and also that variable contributions from an ^{34}S-enriched source have been added along with Cu by the hydrothermal brine. The ratio of sedimentary-diagenetic S to introduced S is poorly constrained because of the probable isotopic heterogeneity of the sedimentary-diagenetic pyrite at the onset of Cu mineralization. The isotopic evidence for large-scale incorporation of sedimentary sulfide S into the epigenetic Cu ores is consistent with the suggestion that the sulfides in the replaced metasediments were an important ingredient in the chemical trap that contributed to the localization of the Cu ores at Mount Isa. (Authors' abstract)

ANNELS, A.E. and ROBERTS, D.E., 1989, Turbidite-hosted gold mineralization at the Dolaucothi gold mines, Dyfed, Wales, United Kingdom: Econ. Geol., v. 84, p. 1293-1314. First author at Dept. Geology, Univ. Wales, College of Cardiff, Cardiff CF1 3yE, Wales.

The Dolaucothi Au deposit occurs in thin bedded turbidites of Upper Ordovician to basal Silurian age deposited near the southern margin of the lower Paleozoic Welsh basin. The host rocks were deformed during the Caledonian orogeny (390-410 Ma).

Au occurs in a variety of hosts including pyritic shales containing both euhedral and framboidal pyrite, quartz-carbonate stringer veins, in steeply or gently inclined veins associated with shear zones and in planar quartz veins associated with the Roman lode. The mineralogy is simple, with pyrite and arsenopyrite being the dominant sulfides. Ankeritic carbonates, hydromuscovite, and the lithium silicate, cookeite, are also present.

It is proposed that, during prograde metamorphism associated with early stages of the Caledonide orogeny, fluids circulated through the basement below the southeast margin of the Welsh basin and leached Au and associated metals, from rocks of igneous or volcanic origin. These overpressured fluids were released to high crustal levels during later orogenic movements and uplifts, perhaps related to reactivation of such basement faults as the infra-Tywi fault. Geothermometric studies indicate that the host rocks experienced upper anchizone facies metamorphism whereas the T of the mineralizing fluids were in the range of 345° to 450°C. Isotopic studies point to a common origin for the sulfides in both the shales and the veins and also indicate that the host rocks provided the source of the carbon now incorporated in the carbonates. (From authors' abstract by E.R.)

NaCl eq. concentration ranged from 2.3 to 18.7 wt %. Mean Th was ~250°C, mean salinity ~7%. (E.R.)

ANSDELL, K.M., KYSER, T.K. and McDOUGALL, Frank, 1989, Gold in the Proterozoic Flin Flon Domain: The Laurel Lake Au-Ag deposit (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-3. First author at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

Au deposits in the western part of the Proterozoic Flin Flon Domain are hosted in a variety of rocks, and regional structural correlations suggest that there are possibly three distinct Au mineralizing events. The Laurel Lake deposit is an example of the earliest event.

The Laurel Lake deposit, 25 km SW of Flin Flon, is confined to Early Hudsonian Amisk Group quartz porphyritic rhyolites and quartz-feldspar lapilli tuffs. It consists of a number of sub-parallel and branching quartz-muscovite-pyrite (+ tetrahedrite, chalcopyrite, sphalerite, galena, Au, carbonate, tourmaline) veins (Stage 1) surrounded by a widespread zone of sericitization and pyritization. The area has been affected by two distinct post-mineralization deformation events, and regionally metamorphosed to low greenschist facies. Later non-auriferous quartz-carbonate-tourmaline-pyrite veins (Stage 2) crosscut foliation.

Rare P inclusions in Stage 1 veins suggest that the mineralizing fluids are high T (>280°C), saline (>26 wt % NaCl eq., halite and nahcolite daughter solids) and CO_2-bearing. S FI in Stage 1 and 2 veins contain dominantly low salinity CO_2-CH_4, N_2-bearing fluids which exhibit evidence for CO_2 immiscibility.

Spatial association with felsic volcanics, high Ag:Au ratio (5:1), pre-deformational deposition, no obvious relation to a major shear zone and FI data suggest that the deposit may be genetically related to the waning stages of Amisk volcanism, and contemporaneous intrusive activity. (Authors' abstract)

ANSDELL, K.M., NESBITT, B.E. and LONGSTAFFE, F.J., 1989, A fluid inclusions and stable isotope study of the Tom Ba-Pb-Zn deposit, Yukon Territory, Canada: Econ. Geol., v. 84, p. 841-856. First author at Dept. Geological Sciences, Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

The Tom Ba-Pb-Zn deposit, Yukon Territory, Canada, is a stratiform, exhalative, massive sulfide deposit, which is hosted by carbonaceous mudstones, turbiditic sand-banded mudstones, and debris-flow, chert-pebble conglomerates of the Upper Devonian Earn Group. The deposit consists of a lens of massive ore (pyrrhotite-galena-sphalerite-ankerite-chalcopyrite) that passes vertically upward and laterally into laminated ore (sphalerite-galena-pyrite-barite-chert). The footwall units host an area of ankerite and quartz veining, which is interpreted to represent the feeder zone for the mineralizing fluids. The ankerite veins are believed to be related to mineralization, whereas fluid inclusion and stable isotope data suggest that the quartz veins formed during one of the postmineralization deformation events.

Th of fluid inclusions from ankerite and quartz range from 157° to 335°C. This range is interpreted to be due to variable leakage from inclusions during deformation and metamorphism and is not representative of T of original entrapment. However, fluid inclusion type and salinity data can be used to distinguish between the mineralizing fluid and the fluid present during later deformation. Ankerite was deposited from an aqueous solution with a salinity of 9.1 ± 3.4 eq. wt % NaCl; tectonic quartz was deposited from fluids with high and variable CO_2 ($\pm CH_4$, N_2) contents and salinities of 4.8 ± 1.3 eq. wt % NaCl. There are distinctive intergrain and intersample variations in the CO_2 contents of inclusions.

A lack of variation in the oxygen isotope compositions of mudstones and <2-μm mineral fractions, plus the absence of an alteration halo around the mineralization, implies that the extent of interaction between the mineralizing fluid and the country rock was small. This may have been the result of a low water/rock ratio, a high fluid-flow rate, and/or a low T (<150°C) for the mineralizing fluid.

The mineral assemblages and paragenesis suggest that early mineral deposition (fine-grained quartz and ankerite) occurred in a sulfur-deficient environment. Local production of reduced sulfur eventually allowed the precipitation of sulfides. The mineral zonation exhibited by the massive and laminated ore is typical of hot, reduced hydrothermal fluids mixing with cooler, more oxygenated water. (Authors' abstract)

AQUINO, J.S., 1989, Ore mineralogy and fluid inclusion studies of Masbate gold operations (Atlas) and the implications to its ore genesis: M.S. thesis, Univ. Philippines.

The Masbate Gold District is one of the known epithermal Au deposits in the Philippines. Several Au occurrences are known in the island, but a good number of them are located on the northernmost portion. Most of these Au-bearing quartz veins are currently being mined by Atlas Consolidated Mining and Development Corporation and are the subject of this research work.

An attempt is hereby presented to synthesize all data based on the regional and mine mapping of the mine site and vicinity, ore mineralogy and fluid inclusion studies. The conclusions arrived at are in no way an attempt to formulate a detailed physico-chemical environment of the vein systems since a lot more data are needed, particularly of each vein system. The conclusions presented serve as an insight and overview of MGO's ore characteristics and paragenesis and the environment by which the ore solutions were formed.

The hydrothermal solutions that form the present-day Au veins of Masbate were deposited in at least three stages or pulsations starting with the ground preparation of the district through the movements of Philippine Fault. The earliest stage is the intrusion of gray quartz with the corresponding deposition of pyrite and other base metals. The next pulse is grayish white to milky quartz with lesser amounts of the ore minerals. And the latest stage is the predominant veining of calcite. Au is believed to have deposited since the earliest stage and gradually waned as T dropped and the fluid composition changed.

The corresponding ore mineralogy produced is relatively simple, with the predominance of pyrite and minor sulfides like chalcopyrite and sphalerite. With a limited textural relationship between the ore minerals, pyrite was deposited initially closely followed by sphalerite and chalcopyrite. Manganite was deposited much later during calcite veining.

Based in fluid inclusion studies, the vein systems of MGO have a dominant liquid phase (L+V) with a 75% to 95% degree of fill. Th varies from 200 to 300°C and a corresponding salinity of 0 to 3.85 wt % NaCl eq. The solutions are presumed to be near their boiling point curve at a depth of 250 m to 800 m below the paleosurface. The mode of transport could be Au bisulfide solutions that ascended through permeable openings and reacted with percolating meteoric waters.

Using Buchanan's (1981) model and correlating it with available data from MGO's vein system, we can conclude that the present mining district has had probably 200 m graded from the paleosurface. An exception to this possibility is the vein system of IXL-Balete wherein the high ratio of base metal sulfides correlate it with the bottom of Buchanan's model. Mitchell (unpublished), on the other hand, categorized Masbate according to his cherty silica model and interpreted the vein system of the mine site to be at the base of his model. Based on Au fineness (Rose and Morrison, 1988), Masbate is within the acceptable range of epithermal Au deposit. (Author's abstract, modified by E.R.)

AQUINO, J.S. and FISCHER, H.H., 1989, Ore mineralogy and fluid inclusion studies of Aroroy gold district, Masbate and their implications to its ore genesis (abst.): Geocon '89, 2nd Annual Convention, Geol. Soc. Philippines, Abstracts (unpaginated). Authors at Nat'l Inst. Geological Sciences, Univ. Philippines.

The Masbate gold Operations and its vicinity is one of the known epithermal Au deposits of the Philippines. Since the beginning of operations in 1980, the mine is one of the leading Au producers in the country with a daily mining production of 3500 tonnes and averaging about 2.0 g Au/ton. The area is underlain by a thick sequence of volcanic and volcanoclastic rocks cut by quartz veins and intruded by later hornblende augite andesite porphyry bodies. Au is present in the quartz veins and its adjacent wallrocks.

Qualitative and quantitative ore microscopic studies reveal a relatively simple ore mineral assemblage. Pyrite is the most predominant phase with minor occurrences of chalcopyrite, sphalerite and manganite. Au occurs as submicroscopic native metal(?) grains. Reflectivity and microhardness tests (VHN) were carried out on the aforementioned minerals to quantify their optical and physical properties. For selected panned Au grains, variations of reflectivity values could be correlated with changing Ag contents of the individual grains.

Fluid inclusion studies reveal that the Th among 10 investigated vein systems in the district range from 200 to 300°C with apparent salinity values from 0 to 3.85 NaCl wt % eq. Correlation of these data with experimental results indicate that during the time of deposition the hydrothermal fluids were not close to their boiling point and the quartz veins formed at a depth of 250 to 800 m from the paleosurface. (Authors' abstract)

ARAL, Halil, 1989, Antimony mineralization in the northern Murat Dagi (western Turkey): Econ. Geol., v. 84, p. 780-787. Author at Dept. Geological Engineering, Hacettepe Univ., Ankara, Turkey.

The northern Murat Dagi region of western Turkey represents the second largest Sb-producing district in Turkey. The Sb ore occurs as stibnite and secondary Sb oxides in hydrothermally altered ultramafic rocks, marbles, and conglomerate. All host rocks were first strongly silicified and open spaces were lined with crystalline quartz prior to mineralization.

The fluid inclusion data as well as the mineralized assemblage supports an epithermal origin, with mineralization at ~165°C. Low salinity (~3 eq. wt % NaCl) of the hydrothermal solution suggests large-scale contribution by meteoric waters. The fluid inclusion data suggest a shallow depth of mineralization (less than 200 bars) by hydrothermal solutions. (From author's abstract by E.R.)

ARANOVICH, L.Ya. and **PERCHUK, A.L.,** 1989, Experimental study of the equilibrium clinopyroxene + quartz + albite in the system Na_2O-CaO-FeO-Al_2O_3-SiO_2 at 900-1100°C and 14-25 kbar: Doklady Akad. Nauk SSSR, v. 307, no. 6, p. 1453-1457 (in Russian). First author at Inst. Exper. Mineralogy, Chernogolovka near Moscow, U.S.S.R.

Pertinent to mineral thermometry and melt inclusion studies. (A.K.)

ARAVENA, R., WASSENAAR, L.I., BARKER, J.F. and **BLISS, M.,** 1989, Geochemistry and sources of methane in the confined Alliston aquifer complex, central Ontario, Canada (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-13. Authors at Center for Groundwater Res., Dept. Earth Sci., Univ. Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Methane gas is a major groundwater contaminant in some parts of the confined Alliston aquifer complex in central Ontario. The aquifer is a major water supply for rural communities and towns such as Alliston, Beeton, and Cookstown.

The extent of methane distribution and the origin of methane in the aquifer complex is not well established, and is presently under investigation. One hypothesis suggests the methane is thermocatalytic whose distribution is controlled by leakage from the underlying Paleozoic bedrock. However, carbon isotopic evidence ($\delta^{13}C$ values of -69 to -89‰, PDB) indicate the methane is biogenic in origin. Thus, biogenic methane is migrating from the bedrock and/or is being produced within the aquifer complex. Gas chromatographic analyses of gas samples indicate 2 main components, methane (±80%, ±2500 umol/l) and nitrogen (±20%, 118-220 umol/l).

Potential methane carbon sources are aquifer/bedrock kerogen and/or Pleistocene age organic-rich deposits. A strong correlation ($r^2 = 0.96$) is observed between methane and dissolved organic carbon concentration in the aquifer complex. High methane concentrations are observed where DOC is greater than 5 mg C/l. This suggests that both carbon pools may be genetically related.

Radiocarbon dating of both methane and DOC is expected to better define carbon sources for the generation of methane in the Alliston aquifer complex. Additional isotopic evidence regarding the genesis of methane and isotope hydrology of the groundwater will also be presented. (Authors' abstract)

ARCE, Osvaldo and **NAMBU, Masateru,** 1989, Fluid inclusion study in the Huanuni Mine, Bolivia: J. Mining and Materials Processing Institute of Japan, v. 105, p. 1073-1078. First author on Faculty of Engineering, Tohoku Univ., Japan.

A study on fluid inclusions in quartz and cassiterite from the Huanuni mine in the western part of Bolivia was carried out. S inclusions along a healed crack show a wide range of Th but a narrow range of salinities. This would suggest that inclusions were trapped from similar solution in different gas/liquid ratios, due mainly to boiling of the ore forming fluid. The mode of occurrence of the fluid inclusions indicates that the fluid boiled frequently at all stages of mineral deposition. Since the lowest Th of those inclusions would be close to the Tt, we conclude that the forming T in the early and late vein stages were about 350° and 100°, respectively. Boiling under conditions of supersaturation also would cause the profuse deposition of fine grain minerals at Huanuni mine. (Authors' abstract)

Shows cross sections of new heating and freezing stages, previously described only in a 1986 Japanese paper. (E.R.)

AREVADZE, D.V., BAINDURASHVILI, T.G., KUPREISHVILI, K.A. and **YAROSHEVICH, V.Z.**, 1989, Ore daughter minerals in fluid inclusions and ore-bearing capacity of hydrothermal systems, USSR (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 2. Authors at Caucasian Inst. Min. Resources, Tbilisi, 380062, Georgia, USSR.

Empirical data obtained during FI studies of hydrothermal deposits in different formations throughout the USSR, indicates the possibility of assessing the ore potential of hydrothermal systems according to the phase composition of FI in the minerals.

Skarn, porphyry and greisen types of mineralization are characterized by multiphase FI containing transparent (halite, sylvite, calcite, anhydrite, etc.) and opaque (pyrite, chalcopyrite, magnetite, molybdenite, etc.) minerals. The fluid ore profile corresponds to the daughter ore mineral in the FI. For instance, chalcopyrite (opaque non-magnetic tetrahedral crystal) for skarn-iron ore deposits; arsenopyrite (opaque needle crystal) for high T arsenic deposits. Pyrite (opaque non-magnetic cubic crystal) and hematite (tabular translucent red crystal) are not indicative of fluid ore potential. Quantitative and volumetric ratios of non-metallic (transparent) dms are additional criteria.

As a rule, no more than three non-metallic dms occur in the mineral inclusions in porphyry Cu and Mo and skarn-Fe ore deposits, occupying at most 50% of inclusions volumes. However, FI containing more than three non-metallic minerals which occupy 70-80% of inclusion volumes are typical of minerals of W and/or Sn bearing skarns and greisens.

The visual method of diagnosing high concentrations of ore components in FI is supplemented by widely developing analytical methods. Thus, F. Reif has demonstrated the efficiency of laser microanalysis of FI, with the purpose of prospecting for Sn-W deposits. (Authors' abstract)

AREVADZE, D.V. and **YAROSHEVICH, V.Z.**, 1989, Fluid inclusions and stable isotopes in antimony-arsenic formation deposits, USSR (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 3. Authors at Caucasian Inst. Min. Resources, Tbilisi, 380062, Georgia, USSR.

A number of typomorphic genetic properties have been revealed as a result of comprehensive studies of FI and stable isotopes in Sb-As deposits of the Caucasus and northeast regions of the USSR.

Ores formed from HCO_3-Cl, Na-Ca fluids with variable amounts of Mg and SO_4 ions. The P fluid was characterized by high As, Fe and S concentrations established according to the occurrence of authigenic needle dm of arsenopyrite in the FI of high T association minerals. The total salinity of the fluids hardly exceeded 100 g NaCl eq. The gaseous component of the fluids comprises CO_2 which often forms a separate liquid phase in the inclusions (at room T).

L inclusion The in the mineral assemblages quartz-arsenopyrite, quartz-antimonite (occasionally with scheelite) and auripigment[orpiment?]-realgar were 420-350°C, 360-230°C and 220-150°C, respectively. Fluid P estimated for pure CO_2 and multiphase inclusions were >1-15 kb. Meanwhile, the orpiment-realgar mineralization was controlled by H_2O-CO_2 fluid immiscibility.

As evidenced by the isotope data for H of the FI water, O and C of the carbonates and S of sulphides, deep-seated emanations (for H_2S and in part CO_2) and host rocks (for CO_2) proved to be the main sources of the hydrothermal fluid components. Water in the mineral-depositing fluids was of primary meteoric origin with possible admixture of a magmatic component. (Authors' abstract)

ARNASON, J.G., BIRD, D.K. and LIOU, J.G., 1989, Calculation of fluid composition from mineral equilibria and implications for compositional zonation in epidote, State 2-14 well, Salton Sea geothermal field, California (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A237.

ARNE, D.C., DUDDY, I.R. and GREEN, P.F., 1989, Thermal histories of Mississippi Valley-type ore districts from apatite fission track analysis (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-54-55. Authors at Univ Melbourne, Parkville, Australia.

In each of the MVT ore districts under investigation, no "thermal halo" associated with sulfide mineralization has yet been identified using apatite fission track analysis. Instead, apparent apatite fission track ages indicate regional heating to T similar to those estimated for ore formation. In the case of southeastern Missouri, the last phase of heating to peak paleotemperatures probably in the range 100-100°C [sic] is likely to have ended at around 50-70 Ma. Devonian carbonates hosting Pb-Zn mineralization on the Lennard Shelf were heated to around 80°C immediately prior to uplift and cooling beginning at 180 Ma, but also probably experienced a phase of heating to paleotemperatures near 100°C in the Late Devonian. The Pine Point District cooled from a single phase of paleotemperatures in the range 80-100°C at some time less than 100 Ma. (From authors' abstract by E.R.)

ARNOLD, M., 1989a, Fibrous structure in natural and synthetic quartz crystals revealed by an interferential method (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 4. Author at C.R.P.G., 15 rue de Notre Dame, 54501 Vandoeuvre l0s Nancy, France.

Optically anisotropic crystals under the conoscope yield interference figures whose geometrical parameters historically gave the first pictures of matter organization in crystals. These crystalline structures are well known today. Nevertheless, the conoscopic studies give some indirect information on the ultramicrostructure of crystals if the change in isochromatic patterns related to wave length variations (the so-called dispersion phenomena) can be interpreted. The ultramicrostructure of natural and synthetic quartz crystals is depicted in this manner. Thin (0.5 mm) optical plates of quartz (parallel or perpendicular to the basal plane) are observed in the 450-1200 n.m. under a classical conoscopic apparatus. In blue light, quartz crystals exhibit uniaxial isochromatic curves. In contrast, biaxial figures are observed in the same crystals in the red and infrared wave lengths investigated. This phenomenon is analogous to the strong dispersion of the rotatory power of quartz. The appearance of a markedly biaxial behavior in the low part of the investigated spectrum can be explained if some predominantly ionic charge carriers are present in a pseudohexagonal superlattice in the quartz crystal. Thus, the quartz crystal acts as a biaxial medium when the lower frequency light causes vibration of ionic charge carriers in the superlattice. The presence of a quartz superlattice is proven by the additional observation of its mean S.E.M. Natural and synthetic quartz crystals are close packed assemblages of quartz fibers. These are parallel to the c axis. Fiber sections are elliptical. The mean diameter is close to 100 n.m. Length of fibers is related to the crystal quality. Thus, fibers as long as 300 μm are found in the nearly perfect "diamond quartz." The low symmetry (2) of the superlattice is in good accordance both with biaxial figures and with diffraction patterns developed in basal sections of quartz by acoustical shortwaves by Schaefer and Bergman. (Author's abstract)

ARNOLD, M., 1989b, Stable versus metastable fluid inclusions? An answer by photoelasticity (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 5. Author at 15 rue Notre Dame 54501, Vandoeuvre l0s Nancy, France.

Monophase inclusions of liquid water are observed in many crystals of quartz and barite in silicified anhydrite veins located on the margins of the Rhine Graben. Were they trapped stably at very low T or were they trapped at higher T and have remained metastable since then? Theoretical and experimental data (Figs. 1-4) indicate that long term metastability is highly improbable, but not impossible. Fortunately, this dilemma can be solved by photoelastic considerations. Indeed, at 20°C, a metastable liquid water inclusion exerts a traction (negative P) on the enclosing crystal. Such a traction induces photoelastic patterns in the crystal. Conversely, the lack of these patterns proves that the FI were trapped at surface T. (Author's abstract)

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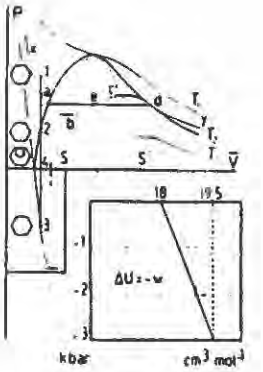
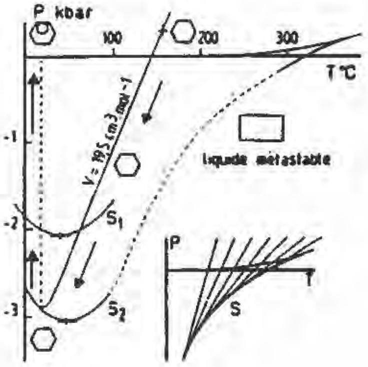




ASH, J.P. and **TYLER, N.,** 1986, A preliminary investigation of fluid-inclusions in the Pilgrim's Rest goldfield, eastern Transvaal: Univ. Witwatersrand Econ. Geol. Research Unit, Information Circular No. 180, 21 pp. First author at Dept. Geological Sciences, Univ. Texas, Austin, Texas.

The Pilgrim's Rest goldfield encompasses a cluster of quartz-pyrite-Au veins that outcrop and subcrop over an area of 600 km^2 in the eastern Transvaal. Most of the veins are found in the Malmani dolomite of the 2200-m.y.-old Transvaal Supergroup; lesser numbers of veins crosscut the granitic basement or follow bedding in the Wolkberg and Pretoria Groups that underlie, and rest on, the Malmani Dolomite, respectively.

Six samples of vein-quartz, two from vertical veins in the basement granite, two from strata-bound, bedded ore-bodies ("reefs") in the dolomite, and two from stockworks that accompany the bedded reefs, were selected for fluid-inclusion analysis. Pilgrim's Rest fluid inclusions are highly complex. Four principal types have been recognized. Type-1 inclusions are entirely aqueous; Type-2 contain mixtures of $CO_2 \pm H_2O + CH_4$; Type-3 are characterized by the presence of variable quantities of dms halite, sylvite, and anhydrite, in addition to liquid and vapor phases; Type-4 inclusions are nearly-pure CO_2. The fluid inclusions are variable in density and composition. Inclusions containing high-density, CO_2-rich fluids are ubiquitous. Aqueous inclusions exhibit moderate-to-high salinities..

T-determinations indicate that the inclusions were trapped under a T gradient of 100°C/km. Inclusions from quartz veins cutting basement granites have Th of 300° to 400°C; inclusions from shallower, strata-bound reefs have Th of 200°C. Each sample displays a range of Th and Td, suggesting that mineralization was probably a multiphase event. Preliminary geobarometry suggests depths-of-formation at 5.5-7.0 km. Pilgrim's Rest fluid inclusions are similar, in many respects, to those of Archean lode-Au deposits. (Authors' abstract)

ASHLEY, P.M. and **PLIMER, I.R.,** 1989, "Stratiform skarns"—A re-evaluation of three eastern Australian deposits: Mineral. Deposita, v. 24, p. 289-298. First author at Dept. of Geology and Geophysics, Univ. New England, Armidale, N.S.W. 2351, Australia.

The tectonic setting, regional geology, regional geophysics, local geology, mineralogy, petrology and geochemistry of three eastern Australian "stratiform" skarns have been investigated. These skarns all show a close spatial relationship to granitic rocks, display multiphase spatial and temporal mineralogical zoning, contain minerals not commonly present in exhalites, contain fluid inclusions characteristic of metasomatic skarns, display textural evidence of replacement of limestone and fossils by calc-silicate minerals, and possess a major element chemistry unlike exhalites. Although some metamorphosed exhalites contain CaFeAlMgMn silicates, the Ban Ban, Brindabella and Willi Willi mineralized skarns formed from metasomatism associated with the emplacement of closely related granites. There is no evidence to suggest that these skarns represent isochemically metamorphosed calc-silicate rich beds of submarine exhalite origin. (Authors' abstract)

ASLANJAN, S., BERAN, A. and HRISCEV, H., 1988, Water content of the inclusions in quartz grains—An eventual sedimentological criterion. Sp. Balg. geol. d-vo, 1988, no. 2, p. 66-71 (in Bulgarian, translation in Bulg. Acad. Sci. Abst. of Bulg. Sci. Lit., 1989, no. 1, p. 8-9).

Quartz grains from the sands of the Ficoza beach to the south of the Cape Galata, Black Sea, were studied. The integral extinction coefficient of Scholze is applied in the IR-spectrographic determination of water in the inclusions. A linear dependence is established between the water content and the average dimensions of the inclusions in the quartz grains. The calculated water content of the inclusions varies between 0.08 and 0.47 wt %. The distribution character of these values shows clearly a bimodality that indicates the presence of two groups. The main group A has a lower water content (<0.27%) and dimensions of the inclusions from 3 to 10 μm. The second group B contains twice as much water (0.40-0.47%) in inclusions measuring from 8 to 13 μm. These results stand for a certain heterogeneity of the sedimentation material of the sands, as far as the discussed criterion affects a conservative feature, reflecting the initial state of the original quartz. (Authors' abstract)

AURISICCHIO, C., DE VIVO, B., FREZZOTTI, M.L. and SCRIBANO, V., 1989, Geobarometry of ultramafic nodules and xenocrysts from Etna volcano on the basis of CO_2 inclusions, Sicily, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 6. First author at C.S. Mineral. e Petrol. Form. Ignee C.N.R., P.le A. Moro 7, 00185 Roma, Italy.

Clinopyroxene xenocrysts and ultramafic nodules are present in the "Ancient Alkaline Lavas" of the Mt. Etna. The host lavas, of hawaiitic composition, consist of labradoritic plagioclase, Ca-rich augite, olivine and Ti-magnetite, also clinopyroxene relics and olivine xenocrysts are often present. The nodules of small size (max 3 cm) are mainly dunite and wherlite characterized by a Cr-diopsidic pyroxene.

S fluid and melt inclusions are present in both clinopyroxene and olivine crystals and can be classified as follows:

(i) Melt inclusions with ultra-low density CO_2 (Raman detection). In addition to glass, clinopyroxene and magnetite are commonly observed.

(ii) Fluid CO_2-melt inclusions, with extremely variable glass content (from <10 up to 50 vol % total). The Th range from 23.3°C to 31.1°C (Th → L = 23.3-31.1°C; Th → V = 24.0-29.9°C) and yield, for a pure CO_2 system, density intervals of respectively 0.45-0.76 g/cm^3 and 0.23-0.39 g/cm^3. Assuming a Tt of 1200°C, the resulting Pt lie in the interval 0.77-4.7 kb.

Microthermometric analyses give a minimum P of formation for the nodules of 4.7 kb, that is, in a hydrostatic P regime a depth >17.7 km ($P_{lit.}$ = 14.5 km). The density distribution suggests a series of interactive fracturing episodes between the nodules and the ascending lava, with a peak at ~3.6 kb (residence in magma chamber?). The xenocrysts do not record any of these events, being the maximum P registered at ~3.4 kb. They show that Pt peak between 1.0-1.5 kb (3.8-5.7 km), which may represent residence in a shallow magma reservoir. The presence of fluid and melt in the same inclusion is good evidence of immiscibility, at times of trapping, between the magma and fluid phase. Immiscibility was probably due to P release. (Authors' abstract)

AWASTHI, A.K., SRIVASTAV and KUMAR, V., 1989, Principal component analysis of common inorganic constituents of waters associated with oil fields, gas fields, and non-petroliferous aquifers (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-64.

AYERS, J.C. and WATSON, E.B., 1989, Solubility of accessory minerals in H_2O at upper-mantle conditions (abst.): Eos, v. 70, p. 506. Authors at Geol. Dept., Rensselaer Polytech. Inst., Troy, NY 12180-3590.

Two different experimental techniques have been used to determine the solubilities of fluorapatite and rutile in H_2O at 20-28 kbar and 1100°C. Measured solubilities of apatite, rutile, and zircon in H_2O are much lower than expected based on chemical and petrographic evidence in natural rocks. Results suggest that supercritical H_2O is relatively ineffective as a transport agent of accessory-phase hosted elements at conditions of the upper mantle. (From authors' abstract by E.R.)

AYORA, C. and **FONTARNAU, R.**, 1989, X-ray microanalysis of frozen fluid inclusions at -140°C (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 7. First author at Dpt. de Cristallog., Mineral. i Diposits Min., Univ. Barcelona, Spain.

Analysis of the elements in frozen solutions is the only way to obtain direct information on the ionic content in solution of a particular FI.

A cryogenic unit, devised for biological purposes, adapted to a Scanning Electron Microscope, permits the observation of samples cooled by liquid N_2. Accessories adapted in the specimen chamber also make it possible to break thin slices of minerals previously frozen by immersion in liquid N_2. A P of $\sim 10^{-5}$ torr prevents the formation of moisture on the fresh broken surfaces and T lower than -140°C are needed to safely remain under the point of ice sublimation. A thin coating of a conducting metal on these surfaces avoids the formation of electrostatic charges and makes it possible to obtain beautiful images of frozen inclusions.

Qualitative analysis of elements heavier than Na is possible by means of an Energy Dispersive System with a Be window. Thus, several inclusions in quartz and fluorite from low T deposits have revealed variable contents of Cl, Na, K and Ca. Droplets and capillaries with solutions of known composition, instantaneously frozen by immersion in liquid N_2, have been tested as standards for semi-quantitative analysis. Amounts as low as 1 wt % NaCl can be easily detected, but compositional heterogeneities on the surface of the frozen solutions have made it impossible to obtain reliable results at the time of writing this abstract. (Authors' abstract)

AYORA, Carlos, LIESA, Montserrat and **SOLER, Albert**, 1989, Quartz vein with As-Bi in Sant Pere, La Jonquera, Eastern Pyrenees [Spain]: Physical-chemical characteristics: Bóletin de la Sociedad Española de Mineralogía, v. 12, p. 351-361 (in Spanish, English abstract). Authors at Facultat de Geologia, Univ. Barcelona, c/ Martí i Franquès s/n., 08028 Barcelona, Spain.

Several quartz veins are associated to late-Hercynian shear zones in the Eastern Pyrenees. The Sant Pere vein is enclosed in one of these zones of kilometric length. Mylonitic deformation affects biotitic schists of Cambro-Ordovician age and granitic intrusives. The resulting paragenesis quartz + muscovite + chlorite belongs to the greenschist facies. The vein, associated to an important increase of quartz in the alteration paragenesis, is formed by several generations of deformation-recrystallization of the quartz. The last episode contains Au in an ore association of arsenopyrite + pyrrhotite + chalcopyrite + native Bi + bismuthinite. Assuming chemical equilibrium among these minerals, they are formed around 440°C, log $aS_2 = -7.4$ and log $aO_2 < -25$. Pyrite is formed after brecciation of former ores, and it is supposed to be contemporaneous to the greenschist alteration. Both the pyrite formation and the greenschist alteration would be caused by the flow of a slightly acidic hydrothermal brine (2.1 m NaCl, $V_m = 20.24$ cc/mol, pH = 5.3). The fluid was trapped as inclusions in quartz at about 270°C and 1 kbar, in conditions near the pyrrhotite + pyrite + magnetite equilibrium (log $aS_2 = -13$, log $aO_2 = -38$). (Authors' abstract)

AYUSO, R.A., BELKIN, H.E., DE VIVO, B., LIMA, A., MESSINA, A. and **SAVA, A.**, 1989, Rock chemistry, fluid inclusion and remote sensing studies as exploration tools for ore deposits in granitic batholiths of Calabria, southern Italy (abst.): XIII Int'l Geochem. Explor. Symp. and II Brazilian Geochem. Congress, p. 55-56. First author at U.S. Geological Survey, MS 954, Reston, VA 22902.

Hercynian granitic rocks found within the Sila, Stilo, Polia Copanello, and Aspromonte Alpine tectonic units in the Calabria-Peloritani arc have a potential as hosts of base- and rare-metal deposits. The granitoids feature a late Hercynian plutonic activity developed probably in an external portion of the Variscan belt.

A reconnaissance FI study has been conducted on samples from the Sila and Stilo tectonic units. S monophase, two-phase (V + L), and three-phase (V + L + halite daughter crystal) aqueous inclusions occur in healed fractures in quartz. Microthermometric heating and freezing experiments reveal a wide range of V/LTh (80 to 420°C), uncorrected for P) and salinity (0 to >26 wt % NaCl eq.) data for both the Sila and Stilo units. Data on first melting of frozen inclusions indicates the presence of additional cations (e.g., Ca^{2+}, Mg^{2+}) in the inclusion fluids. The range of T and salinity in the same sample suggests that the quartz has recorded the passage of various fluids, either during a single hydrothermal event or during events at different times. The salinity and T data found in some inclusions are similar to known mineralized environments in other granitic terranes. (From authors' abstract by E.R.)

AZBEL, I.Y. and **TOLSTIKHIN, I.N.**, 1989, Degassing of the Earth's upper mantle: Dokl. Akad. Nauk SSSR, v. 305, no. 1, p. 195-197 [Geochem.] (in Russian). Authors at Geol. Inst., Apatity, USSR.

Degassing occurs in the lithosphere during the ascent of melt toward the surface and during crustal formation; the event of degassing depends on many factors and varies widely, but the ratio of preserved gases is controlled by the ratio of soly. coefficients (S, with an appropriate subscript for the specific element). Thus, S_{He}/S_{Ar} is ≈10 and S_{Xe}/S_{Ar} is ≈0.3; since 95% of Ar is lost during the degassing of a melt, the concentration and ratio of gases preserved in rocks of the oceanic crust can be estimated. Ocean-crust spreading is not accompanied by intense degassing. Subducted material is mixed and homogenized with upper-mantle material. This resulted in excess fractionation of gases accompanied by an irreversible loss of ^{36}Ar from the mantle material and continuous generation of radiogenic ^{40}Ar with an increase of the ^{40}Ar/^{36}Ar ratio; a comparatively slow degassing of He, on the contrary, ensures the relatively high retention of primary ^{3}He and the high ^{3}He/^{4}He ratio. (CA 110:196724w)

BABAIE, Hassan, HADIZADEH, Jafar and **BABAEI, Abdolali**, 1989, Fluid inclusion study of foliated cataclasites along the Towaliga Fault Zone, west central Georgia (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A65. First author at Geology Dept., Georgia State Univ., Atlanta, GA 30303.

Foliated cataclasites occur with silicified breccias at Dixon Mountain along the Towaliga Fault Zone (TFZ) in western Georgia. The foliation is defined by closely-spaced anastomosing fractures separating elongate grains or aggregates of quartz. Microscopic examination shows that these fractures are commonly aligned with micron- to mm-scale quartz veins, iron oxide, cataclastic seams and zones of microbreccia. Textures indicate that cataclastic seams form by the generation of arrays of intra- and transgranular microcracks, followed by shearing which breaks the quartz grains into long fragments. The fragments granulate and slide past each other while rotating, forming imbricate microstructure and a shape preferred orientation by further shearing. The cataclastic seams that intersect and shear the quartz veins are themselves cut by new veins, indicating multiple cataclasis and fluid injection.

The veined quartz and quartz fragments contain trails of fluid inclusions. Tm ice are -0.7-0°C, indicating salinities of 0-1.2 wt % NaCl eq. Th range from 140-175°C. Assuming $\Delta p/\Delta z = 25$ MPa/km and maximum depth for cataclasis is 6 km, the T of formation of these fluid inclusions is 260-292°C (corrected for the salinity). The existence of tensional radial microcracks in quartz grains within microbreccias and cataclastic seams suggest that the 6 km maximum depth is an overestimation and the T of formation are less than the maximum T stated above.

The mesoscopic and microscopic cataclastic fabric and fluid inclusion data suggest cataclasis and cataclastic flow of the TFZ mylonites and quartzites under lower greenschist facies conditions. (Authors' abstract)

BACON, C.R., 1989, Crystallization of accessory phases in magmas by local saturation adjacent to phenocrysts: Geochim. Cosmochim. Acta, v. 53, p. 1055-1066. Author at U.S. Geol. Survey, 345 Middlefield Road, Menlo Park, CA 94025, USA.

Accessory minerals commonly occur attached to or included in the major crystalline phases of felsic and some intermediate igneous rocks. Apatite is particularly common as inclusions, but Fe-Ti oxides, pyrrhotite, zircon, monazite, chevkinite and xenotime are also known from silicic rocks. Accessories may nucleate near the host crystal/liquid interface as a result of local saturation owing to formation of a differentiated chemical boundary layer in which accessory mineral solubility would be lower than in the surrounding liquid. Differentiation of this boundary layer would be greatest adjacent to ferromagnesian phenocryts, especially Fe-Ti oxides; it is with oxides that accessories are most commonly associated in rocks. A boundary layer may develop if the crystal grows more rapidly than diffusion can transport incorporated and rejected elements to and from the phenocryst. Diffusion must dominate over convection as a mode of mass transfer near the advancing crystal/liquid interface in order for a boundary layer to exist. Accumulation of essential structural constituent elements of accessory minerals owing to their slow diffusion in evolved silicate melt also may force local saturation, but this is not a process that applies to all cases. Local saturation is an attractive mechanism for enhancing fractionation during crystallization differentiation. If accessory minerals attached to or included in phenocrysts formed because of local saturation, their host phenocrysts must have grown rapidly when accessories nucleated in comparison to lifetimes of magma reservoirs. Some inconsistencies remain in a local saturation origin for accessory phases that cannot be evaluated without additional information. (Author's abstract)

Pertinent to the composition of melt inclusions also. (E.R.)

BAGDASAROV, Kh.S. and **ARZUMANYAN, G.A.**, 1988, Origin of vapor-gas inclusions in crystals of leucosapphire: Kristallografiya, v. 33, p. 1040-1056, 1988 (in Russian; translated in Sov. Phys. Crystallogr., v. 33, no. 4, p. 618-628, 1989). Authors at Inst. Crystallography, Acad. Sci. USSR.

We have systematized the literature data on the laws of generation and capture of vapor-gas inclusions in crystals α-Al_2O_3 grown from a melt. We have elucidated the most probable causes of formation and the factors determining the characteristics of the inclusions.

Crystals of leucosapphire, which have found wide applications in various branches of science and technology, possess a unique combination of thermal, optical, and mechanical properties. Among the most widespread defects which impair the characteristics of the crystals are vapor-gas inclusions. So far, the mechanism of formation of the bubbles has not been clarified.

This article is devoted to an analysis of the conditions and causes of formation of vapor-gas inclusions in crystals of α-Al_2O_3 grown from the melt. (Authors' abstract)

BAILEY, D.K., 1989a, Volatiles in alkaline magmatism (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-73.

BAILEY, D.K., 1989b, Carbonate melt from the mantle in the volcanoes of southeast Zambia: Nature, v. 338, p. 415-418. Author at Dept. Geol., Univ. Reading, Whiteknights, Reading RG6 2AB, UK.

Recently Wallace and Green reported the experimental formation of a dolomitic (Ca-Mg) carbonate melt in equilibrium with peridotite minerals in the range 21-30 kbar and 930-1,080°C. These results confirm earlier deductions that, in the presence of CO_2, initial melts from the mantle would be carbonatitic, and extend the conditions of carbonate melt generation. The dolomitic melt composition also endorses earlier observations of quench dolomite after experimental melting of a natural garnet peridotite. Dolomitic ashes, erupted from volcanoes near the confluence of the Rufunsa and Luangwa rivers in southeast Zambia, offer the nearest analogue to the experimental melt yet reported. Quenched melt droplets in the volcanics now reveal new evidence indicating a mantle source for this natural dolomite liquid. Specifically, I present here results which show that the liquid contains magnesiochromite crystals (52% Cr_2O_3) that match those in mantle peridotites, kimberlites and lamproites. In contrast with the experimental liquid, the natural dolomitic melt has a low Fe content, and high Mn and Sr, with alkalies virtually absent. High K activity is recorded, however, in the intensely metasomatized rocks around the main volcanoes. These differences suggest that the mantle source region chemistry differs from the high-Na source envisaged in the experiments. The Zambian carbonatites thus reveal new aspects of carbonate melt and fluid activity in the Earth's mantle. (Author's abstract)

BAILEY, R.C., 1989, Trapping of aqueous fluids in the deep crust (abst.): Eos, v. 70, p. 1324.

BAILEY, R.C., CRAVEN, J.A., MACNAE, J.C. and **POLZER, B.D.**, 1989, Imaging of deep fluids in Archaean crust: Nature, v. 340, p. 136-138. First author at Geol. and Physics Dept., Univ. Toronto, Toronto M5S 1A7, Canada.

Despite the importance of aqueous fluids in tectonic, metamorphic and magmatic activity in the Earth's crust, few techniques are available for directly observing their distribution at depth, even in stable continental crust. Such observations as have been made (electromagnetic deep sounding, which by inference images saline fluids, and super-deep drilling) suggest that fluids are present in varying amounts throughout the crust, in direct conflict with the normal petrological inference of a very dry deep crust. Here we report the results of an unusually high-resolution electromagnetic sounding method to image the deep electrical-conductivity structure below a 30-km profile in Ontario which crosses Archaean lower-crustal material of high metamorphic grade exposed by a Proterozoic thrust fault, the Ivanhoe Lake cataclastic zone. The electrical-resistivity image obtained shows, embedded in very resistive crystalline crust, two nearly continuous, subhorizontal zones of enhanced electrical conductivity at depths of 2-3 and 5-6 km. Below this, the commonly observed mid-crustal rise in conductivity is seen at depths of 15-20 km. The image does not correlate well with the structure inferred from surface geology, suggesting that the transport and distribution of fluids was not strongly controlled by lithological boundaries or the thrust fault itself. (Authors' abstract)

See also "News and Views" report on this paper in Nature, v. 340, p. 102, and Frost et al., this volume. (E.R.)

BAKER, Judy, BICKLE, M.J., BUICK, I.S., HOLLAND, T.J.B. and **MATTHEWS, A.,** 1989a, Isotopic and petrological evidence for the infiltration of water-rich fluids during the Miocene M2 metamorphism on Naxos, Greece: Geochim. Cosmochim. Acta, v. 53, p. 2037-2050. First author at Dept. Earth Sciences, Univ. Cambridge, Downing St., Cambridge, CB2 3EQ, England.

A detailed C and O isotopic study, in conjunction with petrological work, has been carried out across calcite-dolomite marble layers in the high-grade metamorphic sequence on the island of Naxos, Greece. The purpose of this study is to examine fluid flow during the Miocene Barrovian metamorphic event.

Individual marble bands show two dominant styles of isotopic alteration from core values of 22 to 29‰ and $\delta^{18}O$ and 1 to 3‰ in $\delta^{13}C$. Firstly, contacts between the marble bands and surrounding pelitic rocks have altered isotopic ratios across a metre wide boundary layer. The isotopic values of the marble along the contacts drop to 15 to 17‰ in $\delta^{18}O$ and 1 to -5‰ in $\delta^{13}C$. Secondly, there is a drop in the isotopic composition of the marbles along vein networks associated with the development of calc-silicates. The isotopic compositions in these veins drop to 14 to 16‰ in $\delta^{18}O$ and -3 to -4‰ in $\delta^{13}C$.

Cross-cutting relationships observed between these two alterations allow the relative timing of infiltration to be determined. The development of boundary layers is shown to result from the infiltration of fluids with isotopic signatures of 12 to 16‰ in $\delta^{18}O$ and -3 to -12‰ in $\delta^{13}C$, and an XCO_2 less than 0.3 These fluids are derived from dehydration of graphite-bearing pelites during the prograde metamorphism. These conclusions are at odds with those of previous workers who suggested that the prograde metamorphism was a result of the pervasive influx of mantle-derived fluids with XCO_2 greater than 0.5.

The alteration associated with vein networks results from peak to post-peak infiltration of fluids which drive decarbonation reactions. At least some of these fluids have an XCO_2 less than 0.05, but this is obscured by the production of CO_2 during the decarbonation reactions. These fluids were most probably produced from the crystallising partial melts formed during the prograde metamorphism. These infiltrating fluids are thought to have $\delta^{18}O \leq 10‰$ and $\delta^{13}C$ of -5 to -7‰. (Authors' abstract)

BAKER, J., BICKLE, M.J., BUICK, I.S., HOLLAND, T.J.B. and **MATTHEWS, A.,** 1989b, Oxygen and carbon isotopic compositions of marbles: Constraint on fluid movement and composition during Miocene metamorphism on Naxos (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-74.

BAKHANOVA, E.V. and **ANTIPOV, A.F.,** 1988, Use of thermobarogeochemistry data in discerning the origin of gold ores: Issled. v Obl. Poisk i Tekhnol. Mineral., Alma-Ata 1988, p. 60-67 (in Russian). From Ref. Zh., Geol. 1989, Abstr. No. 3Zh115. (CA 111:137742y)

BALL, Philip, 1989, Spreading it about: Nature, v. 338, p. 624-625.

A discussion of a paper by Heslot et al. (this volume) on contact angles of liquids on solids that is pertinent to the trapping of inclusions of a dispersed phase from heterogeneous fluids. (E.R.)

BAMBA, M., HATAKEYAMA, K., KATOH, H., KIZAWA, Y. and **OZEKI, T.,** 1987, Thermal history in the north Hachimantai-Yakeyama area from geothermal alteration and fluid inclusion thermometry: Geothermal Research Society of Japan Meeting, Abstracts (in Japanese, translated by Y. Seki). First author at Mitsubishi Metal Corp.

Geothermal alteration and fluid inclusion thermometry were studied to determine the thermal history of this area. Alteration zoning of zone 1 to zone 6 is recognized based on alteration mineral assemblages as shown in the table. For the most recently drilled well, underground T distribution is considered to have been subject to no recent change and to have maintained boiling curve T from time of fluid inclusion formation to the present. This is based on good agreement between the thermal gradient determined from Th of fluid inclusions, present thermal gradient and boiling T-depth curve for pure water. Provided that alteration minerals are in equilibria with geothermal fluid in this well, the T of formation of these minerals are estimated as follows: chlorite: 140-190°C, wairakite: 210-240°C, epidote: 230-260°C, prehnite: 240-260°C, actinolite: 260-300°C. On the other hand, in some parts of this area the present underground T is 30-50°C lower than the paleo-T, as determined from isothermal contours drawn by the alteration mineral assemblage. (Authors' abstract)

Table 1. Alteration zoning

Alter.minerals	zone 1	zone 2	zone 3	zone 4	zone 5	zone 6
Montmorillonite		----	----			
Chlorite			----	----	----	----
Sericite			----	----	----	----
Chl./Mont.			----			
Seri./Mont.			----	----		
Epidote					----	----
Prehnite					----	----
Actinolite						----
-Cristobalite	----					
Tridymite	----					
Quartz		----	----	----	----	----
Clinoptilolite		----				
Mordenite		----				
Stilbite		----				
Laumontite			----	----	----	
Wairakite				----	----	----
Halloysite	----	----				
Kaolinite		----	----	----		
Pyrophyllite					----	----

BANK, H. and **HENN, U.**, 1989, Colorless, transparent, cuttable sellaite from Brazil: Z. Dt. Gemmol. Ges., v. 38, no. 2/3, p. 143-145 (in German, English abstract).

Colorless, transparent, cuttable sellaite (magnesium fluoride MgF_2) from Brazil is described. Physical and microscopical investigations were carried out. The refractive indices were determined to $n_o = 1.378$ and $n_e = 1.390$ with $\Delta n = +0.012$. The density is 3.15 g/cm^3. Multiphase growth tubes, flat, irregularly shaped cavities with liquid or liquid and gaseous filling as well as three-phase inclusions were found by microscopical studies. (Authors' abstract)

BANKS, D.A., DAVIES, G., GRANT, N., McCAIG, A. and **YARDLEY, B.W.D.**, 1989, The chemistry, source and behavior of fluids involved in Alpine thrusting of the central Pyrenees (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 8. Authors at Dept. Earth Sci., Univ. Leeds, Leeds, UK.

Quartz filled fractures in Silurian black shales above the Gavarnie Thrust, Cretaceous limestones and Triassic red beds beneath the thrust in the Cirque de Barroude and on the Pic de Port Vieux in the Pyrenees contain abundant hypersaline brine inclusions and occasionally hydrocarbons. The veins occupy extensional fractures formed relatively late during Alpine thrusting. From the ice and hydrate melting T it is apparent that the brines have a range of compositions with large variations in the Ca/Na ratio. Individual samples tend to contain only one brine. Salinities are typically 20-25 wt % NaCl eq. and Th have a bimodal distribution of between 130-150°C and 160-190°C.

Chemical analysis of brines leached from 8 samples yields charge balanced analyses for 18 elements (Na, K, Ca, Mg, Al, Ba, B, Li, Sr, Fe, Mn, Zn, Pb, Cu, Rb, F, Cl, Br). Large variations in the Ca/Na ratio (1.3-0.31) correspond to the variations observed from microthermometry. The low K/Na ratios (0.12-0.03) and the presence of hydrocarbons preclude a basement origin for the fluids although the analyses are similar to sedimentary formation waters especially oil field brines. Differences between analyses are likely to reflect different source rock mineralogies.

Sr and Pb isotope analysis were undertaken on extracted fluids and representative country rocks. Rb, Sr and Pb contents range from 4-8 ppb, 200-1600 ppb and 1-4 ppb, respectively. The inclusions show significant variations in both Sr (0.71788-0.73307) and Pb isotopes (206/204 18.7-19.0, 208/204 39.0-39.4). The isotopic data define mixing relationships which are controlled by the fluid compositions (e.g., the low Ca/Na fluids having radiogenic $^{87}Sr/^{86}Sr$ and nonradiogenic Pb isotope values).

Both the fluid chemistry and the isotope values indicate that the fluids are very locally derived, having travelled less than 5 m vertically and 30 m horizontally. The Na-rich fluid originates from the Triassic mudstones and the Ca-rich fluid from the dominantly limestone lithologies. (Authors' abstract)

BANNER, J.L., WASSERBURG, G.J., DOBSON, P.F., CARPENTER, A.B. and **MOORE, C.H.**, 1989, Isotopic and trace element constraints on the origin and evolution of saline groundwaters from central Missouri: Geochimica Cosmochim. Acta, v. 53, p. 383-398.

BANNIKOVA, L.A., SUSHCHEVSKAYA, T.M., KNYAZEVA, S.N., SPASENNYKH, M.Yu. and **BARSUKOV, V.L.**, 1989, Redox conditions of formation of the tin-ore mineralization zones of various productivity: Geokhimiya, 1989, no. 9, p. 1246-1257 (in Russian).

It was previously found that the formation of Sn deposits of the tourmaline type in Komsomolsk ore region (USSR Far East) is controlled by fO_2 variation. Komsomolsk Sn province is characterized by Sn-tourmaline-quartz zones of different productivity with respect to Sn. Comparison of such physico-chemical characteristics as T, P, salt and gas composition of fluid inclusions from minerals of various mineral associations from commercial Sn deposits and barren mineralized zones were made. It was found that the conditions of formation of commercial and non-commercial zones of mineralization were nearly the same in T, P, pH, and concentration of solutes but were sufficiently different in fO_2, controlled by equilibrium of carbon compounds in solution (CO_2, CH_4).

Transport of Sn is supposed to be by reduced fluids during substantial thermal transformation of crustal rocks during granitization. Interaction of fluids separated from granite melt with meteoric waters involved in convective flow around granite intrusion is the important condition for the formation of ore mineralization. Existence of zones with non-commercial mineralization is due either to failure of the fluids to mix, or to the small amount of fluids of meteoric origin that took part in such mixing. (Authors' abstract, revised by T. Sushchevskaya)

BARABAS, A.H. and **McALLISTER, C.A.**, 1989, A crushing stage study of the distribution of carbon dioxide-rich fluid inclusions in veins associated with Mother Lode-style gold mineralization, Bear Valley, California (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 7. Authors at Dept. Geol., MS 24, California State Univ., Fresno, Fresno, CA 93740.

The crushing stage was evaluated as an exploration tool for Mother Lode-style mineralization at Goldenbell Resources' Pine Tree mine project in Bear Valley, California. Approximately 6000 chip samples of vein material were recovered from 22 reverse circulation exploration drill holes, totalling 7975 cumulative feet of exploration drilling encompassing the main ore zone. Veins were also sampled within the ore zone exposed underground in the Pine Tree adit. A standard sized grain of each sample was crushed with the stage and the amount of pressurized gases released into the surrounding glycerine (i.e., the total volume of gas bubbles) was observed at 30x magnification under a binocular microscope. A semiquantitative estimate of the amount of gases released was made on a scale of 0 to 4.

The observed concentrations of pressurized gases are strongly dependent on the mineralogy and the position of the samples in the vein paragenesis. Concentrations are low in early and late stage carbonate minerals (calcite and ankerite) and in lace clear quartz. Milky white quartz, which is particularly abundant within the main quartz veins and the surrounding stockworks, generally has moderate to high contents of pressurized gases. Not all core intervals with milky white quartz veins are mineralized, but microscopic Au is associated with milky white quartz in thin section. Although it is not abundant outside the ore zones, when present, milky white quartz often contains elevated amounts of pressurized gases. Preliminary tests indicate that CO_2 is the principal constituent of the pressurized gases.

The milky white quartz data define a CO_2-rich fluid anomaly or halo that extends a considerable distance into the hanging wall and foot wall outside the ore zones. This anomaly stretches at least 2500 feet along the strike of the Melones fault zone in which the Pine Tree ore zone is localized. The average concentrations of pressurized gases in milky quartz decrease toward both ends of the elongate ore body. (Authors' abstract)

BARANOVA, N.N., DAR'INA, T.G., KOLPAKOVA, N.N. and **KOSERENKO, S.V.**, 1988, Gold determination technique for fluid inclusion solutions and its significance (abst.): Applied Thermobarogeochemistry, Alma-Ata, USSR, 1988, p. 24 (in Russian). Authors at Inst. Geochem. and Anal. Chem., Moscow, U.S.S.R.

The comparison was made between three methods of determination of Au concentrations in fluid inclusions: voltammetric, atomic absorption, and neutron activation analyses. The results demonstrate satisfactory agreement

(±50% limits) of these methods for the range of Au concentration of $7 \cdot 10^{-11}$ - $5 \cdot 10^{-9}$ g/ml of water extract. These values are in accordance with the experimental and thermodynamically calculated data that were obtained under the conditions of inclusion trapping, thus proving the reliability of analytical results. The lower limit of Au concentration in natural hydrothermal fluids is controlled by Au solubility in pure water; the upper limit for its solubility is controlled by significant sulfide sulfur ($>10^{-3}$ M). (Authors' abstract, translated by T. Sushchevskaya)

BARANOVA, N.N., KOLPAKOVA, N.N. and **KOZERENKO, S.V.,** 1988, Boiling of hydrothermal solutions as one of the ore precipitation reasons: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 39-40 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci. of U.S.S.R., Moscow, U.S.S.R.

Fluid inclusions were studied by means of thermobarometric and cryometric studies in vein minerals of Au-Sb and Au-rare metal deposits. Typically heterophase inclusions were found that homogenized at 250-180°C (Au-Sb deposit) and 350-320°C (Au-rare metal deposit). Distinct P decrease was found (1800→500 bar) within one mineral-formation stage. Parent solutions of the two studied deposits differed strongly: high concentrations of CO_2 (up to 5-7 moles), alkali metals up to 0.5 moles, almost complete absence of Cl^- and high concentrations of sulfide ion (up to 0.02 moles), Sb (up to 0.02 mole) and Au up to 10^{-4} mole were found at the Au-Sb deposit. Fluid inclusions from the Au-rare metal deposit yielded the concentrations: CO_2 1-10 moles, alkali metals up to 2-5 moles, Cl up to 4 moles, low concentrations of sulfide ion (up to 10^{-3} mole), Sb (up to $5 \cdot 10^{-4}$ mole) and Au (up to $5 \cdot 10^{-6}$ mole). On the basis of the above data, the equilibria of the Au-complexing reactions were calculated up to T = 300°C. At the Au-Sb deposit Au transport occurred as heteronuclear S-Sb-Au complexes, and at the Au-rare metal deposit, as Au-Cl complexes. P decrease, high CO_2 concentrations and presence of CO_2 and CO_2-H_2O inclusions indicate solution boiling under isothermal conditions that resulted in alkalization, Au complexes hydrolysis and Au precipitation. This was confirmed by experimental data on Au solubility at 350-500°C and 500-1500 atm. (Authors abstract, translated by A.K.)

BARKER, C.E., 1988, Geothermics of petroleum systems: Implications of the stabilization of kerogen thermal maturation after a geologically brief heating duration at peak temperature, *in* L.B. Magoon (ed.), Petroleum Systems of the United States: U.S. Geol. Surv. Bull. 1870, p. 26-29.

BARKER, C.E., 1989a, Temperature and time in the thermal maturation of sedimentary organic matter, *in* N.D. Naeser and T.H. McCulloh (eds.), Thermal History of Sedimentary Basins: Methods and Case Histories: Springer-Verlag, New York, Inc., p. 73-98.

An extensive review, pertinent to many comparisons of such data with Th values. (E.R.)

BARKER, C.E., 1989b, Fluid inclusion evidence for paleotemperatures within the Mesaverde Group, Multiwell Experiment Site, Piceance Basin, Colorado: U.S. Geol. Surv. Bull. 1886, p. M1-M11.

Gas-bearing aqueous fluid inclusions occur in veins cutting the Mesaverde Group in the MWX wells. The fluid inclusions in calcite decrepitate or reequilibrate when heated, and no quantitative Th data can be obtained from them. Fluid inclusions in quartz-lined veins at depths of 5,578 ft (1,700 m) and 7,844 ft (2,390 m) had Th at ~285°F (140°C) and 315°F (158°C), respectively. Modified Th suggest that the fluid inclusions in quartz veins formed in geothermal profile similar to the present-day near-surface T gradient of 2.1°F/100 ft (38°C/km).

Burial T calculated from vitrinite reflectance values indicate a peak paleogeothermal gradient of 2.0°F/100 ft (37°C/km) above 4,400 ft (1,340 m), and a higher paleogeothermal gradient of 4.1°F/100 ft (74°C/km) from 4,400 to 7,950 ft (1,340-2,420 m). The shallow paleogeothermal gradient agrees with a geothermal gradient of 2.1°F/100 ft (38°C/km) measured at depths less than 6,600 ft (2,010 m). Below a depth of 6,600 ft (2,010 m), an increase in coal content causes a higher gradient of about 3.4°F/100 ft (62°C/km). Changes in slope of the measured T profile do not correspond to those in the rank profile or to the gradient suggested by the fluid inclusions. This difference suggests that the geothermal gradient has changed in portions of the well. (Author's abstract)

BARKER, Colin and **SULLIVAN,** George, 1989, Analysis of gases in individual fluid inclusions in minerals from the Kodiak accretionary complex, Alaska (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 8. Authors at Dept. Geosci., Univ. Tulsa, Tulsa, OK 74104-3189.

Quartz and calcite vein samples from the Kodiak accretionary complex, Alaska, contain both CH_4-rich and water-rich FI. Dr. Peter Vrolijk provided material from both the Paleocene Ghost Rocks formation and the Cretaceous Uyak complex. Gases were released by heating samples in a vacuum system that formed the inlet to a pair of fast-scanning mass spectrometers. Each rupturing inclusion produced a burst of gas lasting approximately 2 msec, and gas analysis over the mass range from 2 to 70 amu was carried out in this time frame. Data was recorded on 9-track tape for subsequent processing on a Sun 3/260 computer. Inclusions in quartz showed variable CH_4 contents, but no indications of higher hydrocarbons, CO_2, or sulfur compounds. CO_2/H_2O ratios appeared to be independent of inclusion size. Surprisingly some inclusions contained pure CH_4 with no trace of H_2O. It is difficult to see how these could have formed in a water-wet system. Early trapping of biogenetic gas would have given extremely low internal P on burial. Conversely, deep trapping of thermogenic gas would have produced extremely high internal P on uplift. Lopatin thermal modelling of oil stability in a rapidly subducting cool slab shows that oil can survive very deep (~45,000 feet) so that high CH_4 contents in quartz that crystallized as deep as 70,000 feet may not pose problems. (Authors's abstract)

BARNABY, R.J. and **BODNAR,R.J.,** 1989, Fluid inclusion evidence for high salinity, overpressured fluids associated with MVT mineralization, Cambrian Shady Dolomite, Virginia (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 8. Authors at Dept. Geol. Sci., Virginia Tech., Blacksburg, VA 24061.

In Virginia, MVT Pb-Zn deposits are present in platform margin carbonates of the Lower Cambrian Shady Dolomite. Ore deposition occurred during Late Paleozoic thrust faulting and was preceded by dissolution and brecciation of host carbonates, creating a porous and permeable network for later mineralizing fluids. Ore mineralization was followed by precipitation of saddle dolomite, authigenic quartz, and calcite.

Large S FI (up to 30-40 μm) in authigenic quartz and calcite contain a liquid and vapor phase and halite dms. Th L-V (L) occurred between 110-140°C; while total homogenization (Tm NaCl) occurred at 176-225°C. Salinities, based on Tm (halite), are estimated to be 31 to 33 wt % NaCl eq., assuming a pure $NaCl-H_2O$ system. However, Te (-26 to -25°C) indicate the presence of divalent cations (Ca^{2+} and/or Mg^{2+}).

Minimum Pt, estimated from the intersections of the inclusion isochores with the liquidus curves corresponding to inclusion salinities, range from 430 to 1370 bars. The range of P and T thus obtained exceeds that defined by hydrostatic load (100 bars/km), using the likely range of geothermal gradients (20-35°C/km). The fluids forming the FI, therefore, were overpressured, which is consistent with other evidence indicating the former presence of overpressured fluids.

A minimum depth of formation calculated for the lowest T of total homogenization (176°C) using a geothermal gradient of 25°C/km is ≈6-7 km. This additional P could be generated by tectonic thickening during thrusting. (Authors' abstract)

BARNABY, R.J. and **READ, J.F.,** 1989, Dolomitization of Lower Cambrian carbonate platform during deep burial, Virginia Appalachians, USA (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-89-90. Authors at Virginia Polytech. Inst. & State Univ., Blacksburg, VA.

P fluid inclusions in saddle dolomite (Th = 125-155°C; 23-26 wt % NaCl eq.) and late calcite (Th = 140-150°C; 23-26 wt % NaCl eq.) attest to elevated T during authigenic mineral precipitation. Three-phase (liquid + vapor + halite) S fluid inclusions in authigenic quartz and calcite cement indicate warm (175-225°C) saline (30-33 wt % NaCl eq.) overpressured fluids at 4-7 km depth (Barnaby and Bodnar, 1988). Sulfur isotope geothermometry of sphalerite-galena pairs yields isotopic temperatures of 100-200°C, compatible with the fluid inclusion temperatures. (From authors' abstract by E.R.)

BARNABY, R.J. and **RIMSTIDT, J.D.**, 1989, Redox conditions of calcite cementation interpreted from Mn and Fe contents of authigenic calcites: Geol. Soc. Am. Bull., v. 101, p. 795-804.

BARNES, H.L. and **MASON, S.E.**, 1989, Constraints on the genesis of Mississippi Valley-type deposits from sphalerite banding (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A8.

BARNES, H.L. and **SHENBERGER, D.M.**, 1989, Hydrothermal processes and gold deposition (abst.): Abstract no. 3/2/C, Abstracts Volume, Gold 89 in Europe, Toulouse, France.

For efficient exploration and development of Au ores, realistic models of the concentrating processes are useful. They are constrained by new stability data which show that (1) Au $(HS)_2$ is the common ore-transporting species and (2) few causes of deposition can produce the observed mineral textures and assemblages associated with Au grades in epithermal to mesothermal ores. Buffering of acidity and redox state of the fluid by alteration mineralogy, or by aqueous species where veins are quartz-sealed during cooling, can cause nearly complete deposition over the common range of 350-200°C. Quartz deposition is kinetically comparatively slow in response dominantly to this T decrease and less to vapor release. Similarly effective in depositing Au is oxidation by diffusion of O_2 from vein-surrounding waters or by fluid-mixing. Au solubility also can be decreased by vapor separation of CO_2, H_2S and H_2O slowly over large vertical intervals or abruptly high in epithermal deposits, sometimes forming bonanza ores.

Field clues to Au mineralization are the minerals of the more abundant metals with soft electron shells (Ag, As, Hg, Sb and Tl) which, like Au, also love HS complexes and are deposited by the same processes. Evidence of faster rates of depositional reactions, and of higher supersaturation, is a smaller relative size of vein crystals, especially quartz, Au, chalcopyrite, and pyrite, or a higher ratio of sizes of the (111)/(100) pyrite faces. Coupled with fluid inclusion data, such evidence allows changes in processes of deposition to be identified in both vertical and lateral directions. (Authors' abstract)

BARR, H., 1989, Fluid inclusion studies in a high grade blueschist terrain, Syros, Greece (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 9. Author at Grant Inst. Geol., Edinburgh, UK.

The Island of Syros, part of the Attico-Cycladic metamorphic belt, experienced blueschist facies metamorphism during a subduction related event in the Eocene (40-45 Ma). During uplift a greenschist overprint occurred partially destroying the early high P minerals. Peak PT conditions for the blueschist assemblages determined from experimental data give $T = 470 \pm 30$°C and $P = 14$-19 kb. Oxygen isotope geothermometry yields T estimates between 456 and 625°C, broadly in agreement with the T derived from the mineral phase assemblages.

Detailed petrological work, combined with thermodynamic modelling suggests that the fluid in equilibrium with the blueschist assemblages was H_2O-rich, with less than 5 mole % CO_2 present. In agreement with this, the FI in all the blueschist samples studied are 2-phase aqueous. The inclusions show a broad range of salinity values from almost pure water to halite saturation. First melting T, $T_{fm} < -28$°C, suggest the presence of other salts as well as NaCl. Rare 3-phase inclusions containing a halite dp have salinity values of 34-37 wt % NaCl eq. Although virtually all the FI occur in quartz, some were also found in garnet cores. The latter are of low salinity (4 wt % NaCl eq.) and moderate T (Th range 200-270°C).

FI from 3 samples showing the greenschist overprint were studied for comparison. They are also 2-phase aqueous with a similar Th range to the blueschists (Th 180-340°C). Individual samples show a range in salinities, ≤12 wt % NaCl eq.

Inclusions from unaltered blueschists contain the most saline fluids. In contrast, trails of S inclusions in these samples are of low salinity, comparable with the majority of fluid salinities in the greenschists. However, mineralogical and isotopic evidence suggests that these unaltered rocks have seen little fluid after the peak metamorphic event, and it is therefore suggested that the saline fluids are early. The high salinities in these early inclusionsu, coupled with the isotopic evidence for low fluid-rock ratios in the unaltered blueschists, may reflect prograde hydration reactions, involving lawsonite growth, in a region not being actively flushed by water from deeper levels.

In conclusion, despite the diverse lithologies present on Syros, which include marbles and calcareous schists, the fluids present during both metamorphic events have been aqueous. (Author's abstract)

BARRIENTOS, Ximena and **SELVERSTONE, Jane**, 1989, Greenschist domains in blueschists from Ile de Groix, France: Implications for evolution of fluids in subduction zones (abst.): Eos, v. 70, p. 1377. Authors at Harvard Univ., 20 Oxford St., Cambridge, MA 02138.

A common observation in metabasic blueschists (BS = glauc + epid + gar + mica) from Ile de Groix is the occurrence of domains made up of greenschists (GS = albite + chor + green amph) assemblages. Two types are recognized: (1) continuous folded layers measuring up to 5 m in width; (2) discontinuous 2-7 cm lenses of albite + chlor. Microtextural analyses indicate that the GS domains represent volumes of BS that were selectively overprinted. Combined with mass balance considerations, this suggests that the transition from BS to GS assemblages is defined by reactions such as glauc + gar + epid + H_2O = albite + chlor + green amph. Because water is a reactant, we conclude that the BS domains were preferentially preserved due to low water activities. The geometry of the type (1) GS domain suggests large-scale infiltration, whereas type (2) is consistent with segregation of fluids of different compositions. Segregation may result from differential migration of fluids due to immiscibility. FI analyses support this latter interpretation. Clusters of FI in qtz-epid bands associated with BS contain two types of inclusions: 2-phase saline (NaCl eq = 5.5) and 1-phase FI that may have been trapped from two coexisting immiscible fluids. The 1-phase FI develop a meniscus below -43°C, suggesting the presence of nitrogen and/or carbonic components; the 2-phase FI have variable degrees of filling and Th vary from 154°C to 281°C, but they do not show any evidence of decrepitation. These observations are consistent with trapping of immiscible fluids (Ramboz, 1982).

Other workers (Schliestedt, 1986, Oberhansli, 1986) have reported bulk compositional variations in interlayered BS and GS. This has been interpreted as the *cause* of the interlayering. In Ile de Groix, we see evidence for mobility of Fe^{2+}, Fe^{3+} and Ca: abundant epidote and hematite veinlets are associated with interlayered BS/GS. Therefore, the variations in bulk composition exhibited by coexisting BS and GS may be the *result* of fluid movement associated with overprinting rather than the primary factor in controlling blueschist vs greenschist assemblages. (Authors' abstract)

BARSUKOV, V.L., KOVALENKO, N.I., DOROFEEVA, V.A., BELYUKHANOVA, T.K. and **KHODAKOVSKIY, I.L.**, 1989, Cassiterite solubility in HF + NaF solution at 500°C, pressure 1000 atm, under conditions of the buffer Ni-NiO: Doklady Akad. Nauk SSSR, v. 308, no. 1, p. 157-161 (in Russian).

Sn concentrations in solutions containing from 0.01 HF + 0.01 NaF to 0.5 HF + 0.1 NaF (pH under the run conditions from 5.65 to 3.995) ranged from $(9.46 \pm 1.1) \times 10^{-6}$ to $(1.16 \pm 0.22) \times 10^{-2}$; all concentrations in moles per kg H_2O. (A.K.)

BARTHOLOMEW, P.R., 1989, Interpretation of the solution properties of Fe-Mg olivines and aqueous Fe-Mg chlorides from ion-exchange experiments: Am. Mineral., v. 74, p. 37-49. Author at Dept. Earth and Space Sci., State Univ. New York, Stony Brook, NY 11794, USA.

The ion-exchange equilibrium between synthetic Fe-Mg olivines and 2 molal Fe-Mg chloride aqueous solutions has been bracketed between 450 and 800°C and between 1 and 4 kbar. Additional experiments at lower chloride molalities reveal that the measured distribution coefficient is dependent upon chloride concentration. A detailed aqueous solution model that accounts for the distribution of neutral and charged aqueous species shows that contrasts in the dissociation equilibria of the Fe and Mg chlorides can account for the observed concentration dependence. A tentative value for the first dissociation constant for $FeCl_2$ calculated from the experimental data requires an unexpectedly low hydration number (between 3 and 4). An internally consistent thermodynamic solution model for Fe-Mg olivine is presented; this model was calculated by linear programming from the ion-exchange data and constrained by published independent data. Conflicts between fitting the ion-exchange data and calorimetric constraints on the olivine solution model lead to uncertainties in the accuracy of the employed aqueous solution model. The demonstrated effects of partial dissociation along with unresolved uncertainties in the aqueous solution model indicate that previous solid solution models derived from ion-exchange equilibria with aqueous chlorides may be in error. (Author's abstract)

BARTON, M.D. and **BEBOUT, G.E.**, 1989, Chemical consequences of fluid flow paths in subduction zones (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A85.

BASTOUL, A.M., 1989, The Tichka gold deposit, Morocco: Mineralogical and fluid inclusion data (abst.): Terra abstracts, v. 1, p. 24-25.

The Au showings are spatially associated with [the] contact metamorphism aureole but are mostly located east of the Tichka granodiorite, in a zone which suffered high tectonic deformation. Au occurs in quartz veins with the following paragenetic sequence: (1) quartz-arsenopyrite-pyrite; (2) pyrrhotite; (3) chalcopyrite-sphalerite; (4) native Bi, Bi-telluride, native Au.

Fluid inclusions were studied in the Au-bearing quartz in order to characterize the physical and chemical conditions of the ore deposition. Fluids belong to the CH_4-H_2O (+ H_2S ± CO_2 ± N_2) system and occur as liquid- or vapor-rich inclusions characterized by highly variable proportions of H_2O and CH_4. Such fluid inclusions contain frequently graphite. Th of the volatile phase range from -100 to -75°C, and Tm CO_2 (when present) ranges from -75 to -90°C. The average composition of the fluid obtained from microthermometric and Raman microprobe analyses is the following: 1-10% CO_2; 40-90% CH_4; 20-60% H_2O; 0-6% N_2; 0.5-3% H_2S, with a salinity of 5-6 eq. wt % NaCl.

These mineralogical and fluid inclusion data made possible a reconstruction of the physical and chemical conditions within the gold-bearing veins. At 450-500°C, which represents the T range most probable for the process, the fluid P was around 1.9 ± 2 kbar and the fO_2 around $10^{-26(\pm 2)}$, indicating rather reducing conditions (<Q-F-M) during the thermal metamorphism event. (From author's abstract by E.R.)

BATTLES, D.A. and **BARTON, M.D.**, 1989, Na-Ca hydrothermal alteration in the western Great Basin (abst.): Eos, v. 70, p. 1382. Authors at Dept. Earth and Space Sciences, UCLA, Los Angeles, CA 90024.

Extensive hydrothermal alteration characterized by addition of Na ± Ca, and loss of K, is widely developed in Mesozoic, mainly Jurassic, arc igneous rocks of the western Great Basin from eastern California to central Nevada. Two broad alteration types are developed by age: (1) Triassic/Jurassic alteration in mainly mafic and intermediate rocks (at least 15 localities) and (2) Cretaceous alteration in two-mica granites (three localities). Geological and geochemical evidence suggests that the older alteration is associated with circulation moderately saline, isotopically heavy waters (e.g., formation waters or seawater), perhaps in a rifted arc setting.

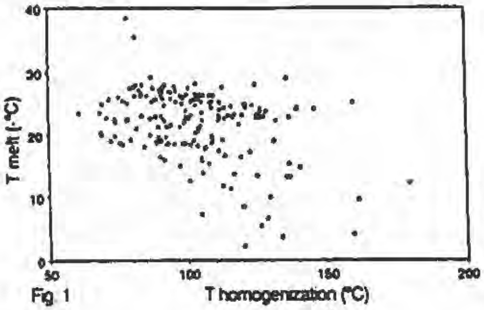
Triassic/Jurassic alteration is of two major types: (1) exchange of Na for K ± Ca (sodic) and (2) fixing of Na + Ca with K loss (sodic-calcic). Whole rock data indicate several weight percent Na_2O and CaO additions, locally exceeding 4 wt % of both, and effectively total loss of potassium. Typical mineralogical changes are: (1) [sodic] interm. plag → alb, K-spr → alb, biot/hbl → chl + mt, and (2) [sodic-calcic] K-spr → olig, biot/hbl → act/cpx. Scapolite and epidote replace feldspar in many occurrences, locally dominating (e.g., scapolitization in the Humboldt lopolith). Complementary alteration in some localities includes sericitic (fldsprs → musc + qz), potassic (secondary biotite ± K-spr), and calcic/endoskarn (fldsprs → cpx + gar ± epid) alteration). Iron (Cortez Mtns, Humboldt lopolith) and Cu (Yerington district) mineralization are local associates. Detailed studies in the Yerington (Dilles, 1984, Stanford PhD thesis; Carten, 1987, Econ. Geol.) and Shamrock batholiths demonstrate temporal and spatial zoning in alteration patterns with older, more proximal sodic-calcic superseded by younger, more distal sodic alteration. Cretaceous alteration is associated with greisenized two-mica granites where sodic metasomatism yields alb (after K-spr) + musc ± qz rocks.

The amounts of added Na (± Ca) FI data, and local halogen-rich assemblages (scapolite ± apatite) require moderately saline fluids in the Jurassic rocks. Stable isotope data for seven Jurassic occurrences indicate that an isotopically heavy water ($\delta D_{water} \geq -70‰$) was involved in Na ± Ca alteration. In contrast, Cretaceous albitization and related alteration are compatible with magmatic and(or) isotopically light waters ($\delta D_{water} \leq -100‰$). (Authors' abstract)

BAUER, R.M., **SHELTON, K.L.** and **GREGG, J.M.**, 1989, Fluid inclusion studies of regionally extensive epigenetic dolomites, Bonneterre Dolomite, S.E. Missouri: Evidence of multiple fluids during Pb-Zn ore mineralization (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A3. First author at Stable Isotope Geology and Geochemistry Group, Dept. Geology, Univ. Missouri-Columbia, Columbia, MO 65211.

Microthermometric measurements of fluid inclusions in replacement and cement dolomite of the regionally extensive basal portion of the Bonneterre Dolomite and in the Viburnum Trend Pb-Zn district indicate the presence of multiple, chemically distinct fluids during dolomitization and Pb-Zn ore formation. T-salinity relationships (Fig. 1) among these inclusions document at least two end-member components: a warmer, less saline fluid (120° to 187°C; 5 wt % eq. NaCl) and a cooler, more saline fluid (60° to 80°C; >30 wt % eq. NaCl). Intermediate fluid compositions indicate that the end-member fluids likely mixed and cooled as they flowed through the region.

Comparison of Th versus distance from possible basinal fluid sources indicates *no* discernible systematic T gradient over the 25,000 km^2 study area. The data are incompatible with a steady-state model of fluid flow from a single basinal source and are interpreted to indicate multiple basinal fluid interactions coeval with dolomitization and associated Pb-Zn ore formation. (Authors' abstract)



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BEARD, J.S. and **LOFGREN, G.E.**, 1989, Effect of water on the composition of partial melts of greenstone and amphibolite: Science, v. 244, p. 195-197. First author at Virginia Museum of Natural History, 1001 Douglas Ave., Martinsville, VA 24112.

Closed-system partial melts of hydrated, metamorphosed arc basalts and andesites (greenstones and amphibolites), where only water structurally bound in metamorphic minerals is available for melting (dehydration melting), are generally water-undersaturated, coexist with plagioclase-rich, anhydrous restites, and have compositions like island arc tonalites. In contrast, water-saturated melting at water P of 3 kbar yields strongly peraluminous, low iron melts that coexist with an amphibole-bearing, plagioclase-poor restite. These melt compositions are unlike those of most natural silicic rocks. Thus, dehydration melting over a range of P in the crust of island arcs is a plausible mechanism for the petrogenesis of islands arc tonalite, whereas water-saturated melting at P of 3 kbar and above is not. (Authors' abstract)

BEBOUT, G.E. and **BARTON, M.D.**, 1989a, Evidence for fluid-related mechanisms of C-recycling in subduction zones from stable isotope systematics in a high-P/T metamorphic complex (abst.): Eos, v. 70, p. 486. Authors at Dept. Earth and Space Sci., U.C.L.A., Los Angeles, CA 90024-1567.

The Catalina Schist, exposed on Santa Catalina Island, southern California, contains metamorphosed sedimentary, mafic and ultramafic rocks that range in grade from blueschist- to amphibolite-facies. Integrated field, petrographic and C-O-isotopic study has allowed identification of C-reservoirs in the subducted slab rocks and determination of C-isotopic compositions of C-O-H fluids evolved in the slab during metamorphism.

Carbonate- and graphite-bearing veins, graphite-bearing pegmatites, CH_4-bearing P FI, and carbonate-bearing metasomatic assemblages document C-mobility in fluids. In low-grade units, carbonate- and graphite-bearing veins are abundant. Excluding the high-$\delta^{13}C$ calcite pods in mafic exposures, the veins have $\delta^{13}C$ values that suggest equilibration with carbonaceous matter in metasediments (blueschist veins, calcite = -13 to -6‰; graphite = -25‰). In amphibolite-grade rocks, pegmatites derived by partial melting of mafic and sedimentary rocks contain graphite with $\delta^{13}C$ (-25 to -18‰) similar to that of carbonaceous matter in metasediments. Calculated CO_2 $\delta^{13}C$ using data for low-grade veins ranges from -10 to -3‰ (mean = -6‰). $\delta^{13}C$ of ankeritic dolomite (-10 to -9‰) in the amphibolite-grade (650-750°C) ultramafic melange (interpreted as a zone of mixing near the slab-mantle interface) suggest C-isotope equilibrium at 650°C with CO_2 of similar $\delta^{13}C$ (-8 to -7‰). This finding is consistent with O-H-isotope evidence that the aqueous fluids which infiltrated the melange were derived in lower-T, sediment-rich portions of the slab. The $\delta^{13}C$ trend of carbonaceous matter could represent progressive fractionation of ^{12}C into CH_4 in fluids. Exchange at inferred metamorphic T with CO_2 of uniform $\delta^{13}C$ of -12 ± 2‰ is also possible, but this range is inconsistent with CO_2 $\delta^{13}C$ values calculated for the low-grade veins (-10 to -3±).

CO_2 $\delta^{13}C$ values calculated from the Catalina vein and graphite data (-14 to -3‰) are similar to those measured in basalts and mantle minerals (e.g., MORB CO_2 $\delta^{13}C$ = -8 to -4‰; back-arc basin basalt $\delta^{13}C$ = -13.2 to -9.8‰; Mattey, 1987). CH_4 $\delta^{13}C$ calculated from Catalina carbonate and graphite data (-35 to -14‰) span most of the $\delta^{13}C$ range of ^{13}C-depleted diamonds. These field-based observations document subduction of reduced and oxidized C and indicate that fluids with C-isotopic compositions similar to mantle compositions may be evolved from subducted materials. C-O-H-isotope systematics in the Catalina Schist suggest that fluid-related processes may be important mechanisms of C-recycling in subduction zones. (From authors' abstract by E.R.)

BEBOUT, G.E. and **BARTON, M.D.**, 1989b, Volatile recycling by devolatilization of subducted sedimentary and mafic rocks—Fluid geochemical evidence (abst.): Eos, v. 70, p. 1376.

The Catalina Schist, exposed on Santa Catalina Island, southern California, contains mafic and sedimentary rocks metamorphosed at 350 to 750°C and 5 to 13 kb. Whole rock analyses show that, during prograde metamorphism from blueschist to amphibolite facies, sediments lost up to 5 wt % H_2O (also up to 550 ppm N and 2.5 wt % CO_2); mafic rocks lost up to 8 wt % water (excluding pore water). Abundant veining and alteration, together with O- and H-isotope homogenization and fluid inclusion evidence, indicate transport of large volumes of aqueous C-O-H-S-N fluid during the high-pressure metamorphism. Metasomatic features contain apatite with up to 2.6 wt % combined F and Cl, demonstrating halogen mobility in the fluids.

The Catalina rocks record voluminous release of aqueous fluid from subducted sedimentary and mafic rocks. Much of this release occurred at sufficiently high T (350-600°C) for volatile retention to great depths. Fluids thus appear to be an effective means of transporting appropriate stable isotope signatures from the slab and could potentially be important sources of mantle wedge volatiles. (From the authors' abstract)

BEBOUT, G.E. and **BARTON, M.D.**, 1989c, Fluid-rock interaction and carbon recycling in subduction zones: Evidence from stable isotope systematics in high-pressure metamorphic complex, Catalina Schist, California (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-108-109.

BEHR, H.J., 1989a, Paleopermeability and fluid flow in crystalline bedrock (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-111. Author at Institut für Geologie und Dynamik der Lithosphare, Gottingen, Germany.

As a rule, various events and generations of fluid inclusions are contained in rock samples taken at the surface. Therefore, the interpretation of fluid inclusions in rock-forming minerals is very difficult and uncertain in these samples. However, the fluid events can be distinguished by cathodoluminescence (CL) as the fluid inclusions, being fillings of residual porosities of various migration impulses, can be genetically classified, thereby possibly improving interpretations of fluid measurements considerably. Often healed decrepitation events which are not detectable by microscopy are made visible in a particularly impressive way. In deep drillings the depth of secondary channelway migration with circulation of meteoric waters in extension channels near the surface can be determined and distinguished from the crustal deep migration of fluids. (From authors' abstract by E.R.)

BEHR, Hansjürgen, 1989b, The geological activities of crustal fluids: Niedersächsische Akademie der Geowissenschaften, Publication Heft 1, Gesteinsfluide, p. 7-42 (in German, English abstract). Author at Inst. f. Geologie u. Dynamik der Lithosphäre (IGDL), Univ. Göttingen, Goldschmidtstr. 3, D-3400 Göttingen, FRG.

A very detailed review (with 63 references) of the evidence for, and the effects of, fluids in the crust, particularly their movement during tectonism. Includes a review of the extensive studies in FRG of the composition and microthermometry of inclusions from the Damara Orogen, as well as from numerous German ore deposits, and comparison with interstitial brines in crustal rocks. Many excellent photomicrographs showing the usefulness of cathodoluminescence in understanding FI are presented. (E.R.)

BEHR, H.J., **ERLINGHAGEN, P.** and **HORN, E.E.**, 1989, Investigations of fluid inclusions in siderite veins in the Siegerland-Wied district (Rheinisches Schiefergebirge, FRG) (abst.): Terra Abstracts, v. 1, p. 33. Authors at Inst. Geol. and Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400, Göttingen, FRG.

This study contains the results of work on FI in siderite, quartz, sphalerite, calcite, barite and ankerite in the Siegerland-Wied mining district. A mineralization sequence was distinguished: Variscan mineralizations of the early phase (quartz-danaite), the main phase (siderite-quartz), the sulphide phase, hematite phase and post-Variscan mineralizations of the late phases (quartz-chalcopyrite, quartz-ankerite, silver-poor galena, antimonite).

Based on the distinctive differences in T and/or composition, the hydrothermal mineralizations can be assigned to three successive fluid systems. The magmatic-hydrothermal solution ($NaCl-MgCl_2-H_2O \pm CO_2$) is characterized by an increase of total salinity (Tm -2°C to -10°C) and a decrease of Tt from 300°C to 130°C during the development of the main Variscan mineralization to galena in the upper level of the sulphide phase. As shown by the microthermometric results the solutions of the second system have a very low NaCl content and in the paragenetic sequence Tt rise considerably to 33°C (quartz 5) [sic]. The rejuvenation in the Siegerland-Wied area begins at calcite 1 and barite of the sulphide phase.

In contrast, the salinities and the NaCl/KCl-$CaCl_2$/$MgCl_2$ dominance in analyzed post-Variscan mineralizations (quartz-chalcopyrite, quartz-ankerite) correspond to brines to be discovered in numerous basinal structures of the earth. According to hydrostatic P correction the maximum Tt hardly exceed 180°C. (Authors' abstract)

BEHR, H.J., and HORN, E.E., 1989, Relations between deposit and rock fluids in selected crystalline regions of central Europe (abst.): Terra Abstracts, v. 1, p. 33. Authors at Inst. Geol. and Dynamik der Lithosphäre, Goldschmidstr. 3, D-3400, Göttingen, FRG.

The investigated areas (Schwarzwald, Odenwald, Spessart, Oberpfalz) were studied by microthermometry and cathodoluminescence. Data on the chemical composition were obtained with INAA, REM+EDX and Raman microprobe. In investigating the granite fluids ICP and O^{18} analyses were additionally carried out, in investigating deposits S-isotope analyses were carried out.

At least two large fluid groups can be distinguished in relatively high-T to high-T low-saline and low-T highly saline inclusions. According to their origin the investigated samples revealed partly clearly separated or overlying fluids within these fluid groups.

In contrast with other central European basement complexes, investigated gases (CO_2, CH_4, N_2) are almost entirely lacking in the rock fluids and vein mineralizations. Also there is extraordinarily high residual porosity of ≥5 vol % in many areas of the anatectic and metablastic gneisses.

The local granite alterations and the important post-Variscan vein mineralization similar to those of the other areas investigated have to be distinguished from these fluid events. According to results of inclusion chemistry the latter can be inferred from marine-influenced basinal brines. Presumably, mixing of these basinal brines with ascending low-saline, but warmer fluids took place and resulted in mineralization. (From authors' abstract by E.R.)

BEHR, H.J., HORN, E.E. and six others, 1988, Evolution of fluids in rocks and ore deposits in central and southern Schwarzwald (abst.): Fortsch. Mineral., v. 66, Beiheft 1, p. 13 (in German).

The studies were performed by means of cathodoluminescence, microthermometric (fluid inclusion) measurements, INAA, electron microprobe and Raman probe, as well as ICP-mass spectrometry. At least two large groups of fluids were distinguished: (a) high temperature, low salinity, and (b) low temperature, high salinity. Because in many cases the age of the specimens was known, it was possible to attribute the fluid systems to a Variscan or post-Variscan age. The results of the studies yielded a really distinct pattern of the fluid evolution of the crustal origin in the central Schwarzwald that were trapped in fluid inclusions. The following unusual features may stimulate a genetic discussion in the future:

1. Almost complete absence of CO_3, CH_4 and N_2 in fluid trapped in minerals of rocks and veins, unlike the other studied basement complexes in Central Europe.

2. Very high porosity, about 5 vol % and more, found in many masses of anatectic and metablastic gneiss.

Pre-anatectic inclusions were completely removed, and during the anatexis (Caledonian or Variscan?) new inclusions were formed. The system during its uplift connected with the Variscan tectonic activity was subjected to a polyphase channelway flow connected with hydrothermal alteration.

Local granite alterations and undoubtedly post-Variscan vein mineralization differ distinctly from the above processes. They were caused by marine-water-influenced basin-formation brines. The stated mixing of the cool brines with uplifting low-salinity warm fluids caused the ore mineralization. (Authors' abstract translated and shortened by A.K.)

BELKIN, Harvey, 1989, Fluid inclusion and mineralogic studies of a PGE anomaly zone in the Reeser's Summit (PA) diabase: Evidence for hydrothermal transport (abst.): PACROFI Abstracts with Program, v. 2 [Second Pan-American Conf. on Research on fluid Inclusions, Jan. 4-7, 1989, VPI & SU, Virginia], p. 8. Author at MS-959, U.S. Geol. Survey, Reston, VA 22092.

See abstract in Fluid Inclusion Research, v. 21, p. 28.

BELKIN, H.E. and **DE VIVO, Benedetto,** 1989, Glass, phlogopite, and apatite in spinel peridotite xenoliths from Sardinia (Italy): Evidence for mantle metasomatism (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 20. First author at U.S. Geological Survey, 959 Nat'l Center, Reston, VA 22092.

Spinel peridotite xenoliths hosted by Pliocene to Quaternary alkaline to subalkaline volcanic rocks have been studied from the Lugodoro and the Dorgali areas in west and east central Sardinia, respectively. The occurrence of glass, phlogopite, apatite and CO_2 inclusions are evidence that metasomatic processes operated in the lower crust/upper mantle region of the Sardinian/Corsican microcontinent prior to xenolith entrainment and ascent in the host magmas.

Phlogopite and apatite have been found in one lherzolite (A422). The phlogopite occurs as clusters of anhedral crystals, 20 to 800 μm in size, and is relatively uniform in composition: Mg/(Mg + FeT) ~ 0.88; TiO_2 = 4.4; BaO = 0.35; Cr_2O_3 = 0.44; F = 0.35; Cl = 0.12 (wt %, microprobe). The apatites are small (100 μm) anhedral crystals that occur at triple junctions in textural equilibrium with the silicate assemblage and appear to have formed before or during the last silicate equilibration. The apatites contain F = 1.3, Cl = 1.7, SrO = 1.3, REE ≥ 1.0, SO_3 = 0.2, and MgO = 1.0 (wt %, microprobe) and trails of S CO_2 fluid inclusions.

Glasses occur as thin, irregular veins between phases or associated with CO_2 fluid inclusions along healed fractures in both peridotites and megacrysts. Some glasses in the megacrysts contain a distinctive rapid quench texture of skeletal clinopyroxenes. Microprobe analyses (>100) show two different populations. The augite megacrysts contain a relatively low silica, high iron glass, whereas the spinel peridotites contain a higher silica, lower iron glass. The glass composition are: (avg wt % (1σ)]

Spinel peridotites: SiO_2 = 57.81 (4.50), TiO_2 = 0.35 (0.29), Al_2O_3 = 25.66 (3.45), FeOT = 0.74 (0.55), MnO = nd, MgO = 0.30 (0.49), CaO = 6.93 (3.62), Na_2O = 5.30 (1.07), K_2O = 2.57 (3.05), P_2O_5 = 0.14 (0.17).

Augite megacrysts: SiO_2 = 48.19 (2.03), TiO_2 = 1.93 (0.39), Al_2O_3 = 19.88 (0.93), FeOT = 11.24 (2.87), MnO = 0.22 (0.07), MgO = 2.12 (0.94), CaO = 6.28 (2.11), Na_2O = 4.66 (1.69), K_2O = 3.14 (1.28), P_2O_5 = 0.87 (0.22).

The highest value of K_2O (13.06 wt %) measured in a glass was not from the phlogopite-bearing xenolith.

The xenoliths are hosted in alkali basalt, basanite, hawaiite, and trachybasalt. The glass in the augite megacrysts can be attributed to remnants of its host magma. However, the glasses in the spinel peridotites are unrelated to the host magma. There is also no compositional or textural evidence that these glasses were generated by simple decompressional melting of phases now observed in the xenoliths. We suggest that mantle metasomatism, operating in the spinel peridotite stability field, introduced CO_2-rich silicate fluids. Furthermore, multiple metasomatic stages are indicated by the textural relationships among the modal phases, glass, and CO_2 fluid inclusions. (From authors' abstract by H.E.B.)

BELKIN, H.E. and **RICE, C.L.,** 1989, A rhyolite ash origin for the Hazard No. 4 flint clay (Appalachian Basin): Evidence from silicate-melt inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A360. Authors at U.S. Geological Survey, Reston, VA 22092. [Note: Verbal presentation cancelled. (E.R.)]

Quartz, apatite, zircon, amphibole, and feldspar have been separated from the flint clay parting of the Middle Pennsylvania Fire Clay coal (Hazard No. 4) in the central Appalachian basin. The dark-gray to light-brownish-gray parting is composed of well-crystallized kaolinite (~99%) with accessory minerals. The thickness ranges from <1 to ~20 cm, and the deposit extends discontinuously from central West Virginia to northeastern Tennessee, and underlies ~42,000 km^2. The compositions and petrography of the trapped silicate-melt inclusions and their hosts indicate that the quartz, apatite, zircon, amphibole, and feldspar are cogenetic phenocrysts from a rhyolitic magma. The quartz typically occurs as rounded to euhedral beta-forms (~1 mm); silicate-melt inclusions are common (± bubble). Glass that is completely surrounded by the host shows no evidence of devitrification. Apatite occurs as euhedral zoned crystals (≤1 mm) and as euhedral inclusions in quartz and zircon. All three apatite populations have an identical composition (microprobe wt %: F = 3.20, Cl = 0.15, REE ≃ 1.00). Euhedral zircon has oscillatory zoning and contains common silicate-melt and solid inclusions. A rare green, Cr-rich (Cr_2O_3 = 1.5 wt %) calcic amphibole also contains silicate-melt inclusions. Sanidine (Or = 71.4, Ab = 23.3, An = 1.8, Cn = 3.5) occurs as subhedral to euhedral crystals. Plagioclase occurs as discrete crystals and as inclusions in quartz. The occurrence of cogenetic, uniformly euhedral apatite together with rounded to euhedral beta-quartz forms suggests that the rounded quartz records pre-eruption resorption rather than fluvial abrasion. Silicate-melt inclusions trapped in quartz, zircon, apatite, and feldspar are rhyolite glass having a uniform (>70 analyses) composition within the limits of the microprobe technique; (avg. wt %: SiO_2 = 72.9, TiO_2 = 0.19, Al_2O_3 = 12.34, FeO^T = 1.04, MnO = 0.04, MgO = 0.11, CaO = 0.56, Na_2O = 4.5 (minimum value), K_2O = 5.76, P_2O_5 = 0.05, F = 0.13, Cl = 0.04, BaO = 0.07, total = 97.7). The compositional similarity and interrelationships of the silicate-melt inclusions and their various hosts strongly suggest that the Hazard No. 4 fire clay represents the distal products of a large silicic volcano which is probably associated with one of the Hercynian granitic plutons in the eastern part of the Piedmont. Furthermore, the analysis of silicate-melt inclusions in similar clay horizons throughout the Middle and Upper Pennsylvanian strata may provide a valuable technique for determining correlation and volcanic provenance. (Authors' abstract)

BELLIS, Diane and WOLBERG, D.L., 1989, Fluid inclusions in fossil resins as indicators of paleoatmospheres and environments (abst.): J. Vertebrate Paleontology, v. 9 (3 Suppl.), p. 13A. Authors at New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801.

Fossil resins, commonly present in sedimentary rocks, range from the Jurassic to the Holocene (earlier occurrences are questionable. Resins contain a great deal of information in their physical structure and chemical composition that is of use of paleontology. In addition, they contain FI that range in size from seven micrometers to several mm and in which there may be L and/or G of various origins. Included water has distinctive isotopic signatures. G may consist of original paleoatmosphere, G included during resin synthesis, products of polymerization processes, biodegradation products, and G originating from diagenesis. We have analyzed fossil resins that range in age from Cretaceous through Holocene. Analyses of Cretaceous resin from several localities in the U.S. and Canada do show elevated oxygen levels but the significance of this is unclear. In order to constrain depositional variables, we have sampled and analyzed resin from a continuous 304 ft core and related outcrops of the Fruitland Formation (Campanian/Maastrichtian). (Authors' abstract)

BELOCKY, R., 1989, Fluid inclusions from East Alpine mineralisations; PT-conditions of ore formation including calculation of bulk density and pressure estimate for inclusions homogenizing by halite dissolution (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 51. Author at Inst. f. Geologie and Paläontologie, Technical Univ., D-3300 Braunschweig, F.R.G.

A common feature of the fluid inclusions from mineral deposits possibly related to Alpine metamorphism in the eastern part of the Eastern Alps like Schendlegg (siderite-quartz), Kleinkogel (barite-quartz), Rabenwald (talc) and Erzberg (siderite) are highly saline aqueous solutions with salinities up to 40 wt % NaCl eq., with Th (Tm NaCl) $\leq$ 300°C. Transport of metal ions by chloride complexes is supposed.

P estimations for these inclusions were not yet available. Following the method outlined by Roedder and Bodnar (1980) and Roedder (1984), fluid bulk densities depending on Th ($0 < T_H < 600$°C) and T_S (Tm NaCl) ($0 < T_S < 600$°C) were calculated. P estimates for fluid inclusions with $T_S > T_H$ were carried out by extrapolation of isopleths in P-density projections of the system H_2O-NaCl, using data from Urusova (1975) and diagrams from Walther (1981, 1988).

Fluid inclusions from the central part of the Eastern Alps like from Gastein (Au-quartz veins) and from Hüttenberg (siderite-quartz) show considerable CO_2. In Gastein two Au precipitating fluids were discriminated, the first one showing 70 wt % CO_2, 6 wt % NaCl eq. and T_H of 370-420°C into vapour phase, the second one composed of low saline aqueous fluids with T_H at 150°C. Using the V-X-projection of the pseudobinary system H_2O (+6 wt % NaCl) - CO_2 (Günther, 1989), minimum P for the CO_2-bearing fluid was determined to 750-1000 bar. According to investigations of Henley (1972) concerning solubility of Au in different chemical complexes, metal precipitation in the Au-quartz veins of Gastein occurred at 400-450°C and 1-1.2 kbar for the first time and below 200°C and lower P for the second time.

Fluid inclusions from the siderite deposit of Hüttenberg show 35 wt % CO_2, 6-8 wt % NaCl eq. and T_H of 320-330°C. Considering the stability of siderite in the system Fe-C-O-H, fO_2 (Frost, 1979) and the fluid isochore calculated according to Nicholls and Crawford (1985), ore formation took place at 320-400°C and 2-3 kbar. (Author's abstract)

BELOCKY, R. and POHL, W., 1989, Preliminary fluid inclusions data on some east Alpine hydrothermal mineral deposits in eastern Austria (abst.): Terra Abstracts, v. 1, p. 33. Authors at Inst. Geol. and Paleon., Tech. Univ., P.O. Box 3329, D-3300 Braunschweig, FRG.

[We will study] FI characteristics of Au-quartz veins (Nassfeld/Salzburg, Kothgraben/Styria), barite-quartz (Kleinkogel/Lower Austria), siderite-quartz (Grillenberg, Schendelegg/Lower Austria), a "kaolin" (sericite-chlorite) deposit (Aspang/Lower Austria) and talc (Rabenwald, Lassing/Styria).

The project's ultimate aim is to investigate a possible metamorphogenic derivation of the respective fluids, as large masses of fluids should have been produced either from the unmetamorphosed sediments of the Penninic unit while being subducted underneath the advancing East Alpine pile of nappes in the Cretaceous or during Tertiary heating of the resulting orogenic edifice. (From authors' abstract by E.R.)

BELONOSHKO, A.B., 1989, The thermodynamics of the aqueous carbon dioxide fluid within thin pores. Geochim. Cosmochim. Acta, v. 53, p. 2581-2590. Author at Institute of Experimental Mineralogy, U.S.S.R. Academy of Sciences, 142432 Moscow District, Chernogolovka, U.S.S.R.

The density functional method was used to study the properties of a binary mixture H_2O-CO_2 confined within an infinitely long cylindrical pore of 8 to 25 Å in diameter, over a wide range of T, P and compositions. Interaction with pore walls was calculated through the use of van der Waals and Kazimir-Polder attractive forces; the intermolecular interaction was calculated by means of the spheric-symmetrical approximation. The calculations show that the pore fluid differs markedly in composition from the bulk fluid with which it is in equilibrium at the same T and P. The difference diminishes regularly with increasing pore size to become negligible at a pore diameter of 25 Å. The results of the work presented here provide a physical explanation of the Johannes-Schreyer (1981) experiments. Reasons are offered for the predominantly CO_2 composition of fluid inclusions formed from the fluid of aqueous bulk composition. The relationship between the size of fluid-filled pores and the geometry of the MgO-SiO_2-H_2O-CO_2 diagram in the T-XCO_2 coordinates is discussed. The low activity of H_2O during metamorphism has been explained. (Author's abstract)

Of pertinence also in the problem of the representation of the fluid trapped in ordinary fluid inclusions. (E.R.)

BENETEAU, S.B. and RICHARDSON, J.M., 1989, Fluorine content of topaz: Variation within geological environments (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-82.

BENGOCHEA, A.L. and VARELA, M.E., 1988, The fluid inclusions of the Vein "Susana Beatriz," Angela Mine, Province of Chubut [Argentina]: Asociacion Geologica Argentina, rev., 1988, 43(4), p. 462-473 (in Spanish, English abstract).

The fluid inclusions of the Vein Susana Beatriz, Mina Angela are studied and the characteristics of the quartz crystals and the FI of the ore shoots have been determined by means of the petrographic study. The fluid inclusion study suggests that the ore mineral deposition occurred at T between ~270 and 390°C, at depths of 1500 m and at P near 120 bars. Boiling has played an important role in the precipitation of metals. (Authors' abstract)

BERDNIKOV, N.V. and KARSAKOV, L.P., 1985, Fluid behavior at the time of amphibolite facies metamorphism in the Stanovoi complex (Soviet Far East): Geol. Pac. Ocean, v. 3, p. 39-54. Authors at Inst. Tectonics and Geophysics, Kim-Yu-Chen, 65 680037, Khabarovsk, U.S.S.R.

The Stanovoi rock complex within the Stanovoi Range is a classic example of the amphibolite facies. Here, fluid inclusions have been studied in quartz, disthene [kyanite], fibrolite [sillimanite], garnet, and feldspars from the Kupuri, Ilikan, and Ust'-Gilyui groups. It has been established that CO_2 predominates in the fluid, and that the appreciable amount of H_2O is related to post-Stanovoi metamorphic processes.

The intensity of Stanovoi metamorphism was laterally nonuniform. The disthene-bearing parageneses of the Kupuri and Ilikan groups formed at 600-630°C and 3.3-7.8 × 10^8 Pa. At lower P (3.5-6.6 × 10^8 Pa) sillimanite crystallized and liquid nitrogen [sic] relict inclusions were preserved in the Ust'-Gilyui group. The findings suggest that the largely nitrogen degassing of the Earth in the Archean may have been areal in character. The extent of diaphthoresis in the rocks of the complex varies widely, as follows from petrological and thermobarogeochemical indications. (Authors' abstract)

BERDNIKOV, N.V. and **KARSAKOV, L.P.**, 1988, Fluid regime of transformation of early Precambrian complexes in Phanerozoic fold systems (abst.): Tectonics of Eastern Asia and Western Pacific Continental Margin, Sixth Japan-Soviet Geotectonics Symposium, Tokyo, 1988; DELP Publication No. 22, p. 88. Authors at Inst. Tectonics and Geophysics, Kim-Yu-Chen, 65 680037, Khabarovsk, U.S.S.R.

The study of evolution of material composition and fluid regime in the process of block transformation of Early Precambrian complexes is essential to ascertain the nature of their metallogenic specialization, and also is of interest for solving common problems of formation of the continental earth's crust. Fluid regime of the old blocks transformation is the reflection of fluid regime of the global geodynamic processes which effect these transformations (Berdnikov, Karsakov, 1986). Thus, such investigations make it possible to judge about fluid regime of such processes as geosynclinal, activization, remobilization, reduction of the earth's crust, etc. Moreover, in a number of cases such an approach is most informative. Thus, for example, it may be difficult to study the dynamics of volatiles in the geosynclinal process from the very thick geosynclinal series. First, it is complicated to find the "starting-point" for investigation among geosynclinal assemblages, i.e., to determine "pregeosynclinal" fluid specialization of the thick units and composition of the first portions of "geosynclinal" fluid. Second, in weakly metamorphosed geosynclinal rocks it is often impossible to find informative minerals in terms of thermobaro-geochemistry, large, transparent, preserved during the whole process. Blocks of old metamorphic rocks are more suitable in this respect. Early generations of metamorphogenic inclusions inform of their initial fluid specialization. Superimposed inclusion generations formed in the process of transformation would then contain "geosynclinal" fluid. Besides, deeply metamorphosed rocks (especially metapelites) contain abundant minerals—quartz, garnet, polymorphs of Al_2SiO_5, and others fit for inclusions study.

In the Far East, ancient complexes are exposed on the shields, in the basement of median massifs and in the nuclei of dome structures of Paleozoic-Mesozoic fold systems. By geologic-geophysical properties, activized, reduced and remobilized blocks are recognized among them.

Early Precambrian complexes of the Stanovoy fold area, Omolon median massif underwent mainly block deformations (activization). So, these rocks have preserved carbon-dioxidic fluid specialization characteristic of the oldest deeply metamorphosed complexes.

For the reduced and remobilized blocks which are distinguished by more intensive reworking both of the structure and matter, methane fluid specialization in the inclusions is characteristic. Incidentally, the more deep-seated the process, the thicker turns methane in the inclusions; an appreciable amount of CO_2 which becomes predominant on the level of the granulite facies is added to it. Thus, methane in the old blocks is of superimposed "geosynclinal" nature and has been transported into them in the process of transformation in the Phanerozoic fold systems. (Authors' abstract)

BERDNIKOV, N.V., KARSAKOV, L.P. and **LENNIKOV, A.M.**, 1989, Problem of water in autonomous anorthosites: Doklady Akad. Nauk SSSR, v. 305, no. 6, p. 1433-1436 (in Russian). Authors at Inst. Tectonics and Geophysics of the Far-East Division of Acad. Sci. USSR, Khabarovsk, USSR.

Fluid and solid inclusions have been studied in minerals of the Dzhugdzhur anorthosite massif (E. Stanovoy Ridge) (Sr/Rb age, 2.93 ± 0.1 b.y.). The massif consists of anorthosites, gabbro-anorthosites with schlieren of norites, gabbro-norites, sometimes pyroxenites, with overlapped alteration to epidote-amphibolite facies and a local contact alteration under the conditions of the pyroxene-hornfels facies beside rapakivi-like granitoids (South Uchur massif, 2 b.y). Specimens for fluid inclusion studies have been taken in the least altered parts of the anorthosite massif. Fluid inclusions occur rarely; plagioclase bears solid, solid-fluid and fluid P and PS as well as fluid S inclusions. They consist of a greenish anisotropic silicate(?) and opaque ore in a 5:1 volume ratio. During heating of these inclusions at 980°C the filling starts to melt, at 1180°C the ore phase dissolves, and at 1200-1210°C total homogenization occurs. Seemingly, these ore-silicate inclusions formed during the plagioclase crystallization either as immiscible melt droplets or as a plagioclase-free remnant of a formerly homogeneous melt inclusion, whereas the plagioclase component crystallized inside the inclusion on its walls. Combined P and PS inclusions bear prevailing solid phase with a "sticking" liquid, which is LCO_2 with Tm -56.6°C, Th from +4 to +22°C and Th from -1 to +20°C [sic] in purely fluid inclusions. S inclusions in plagioclase occur in connection with fractures, filled also with mica aggregates. Seemingly, a H_2O-CO_2 fluid penetrated the fractures, H_2O reacted with plagioclase to form micas, and the CO_2 component gave LCO_2-filled inclusions (Tm -56.6°C, Th from +11 to +23°C). H_2O-bearing inclusions in plagioclases from anorthosites have not been found. Rare veins of anorthosite pegmatite consist of plagioclase with nests of apatite, ilmenite, titanomagnetite and orthopyroxene. Apatite bears numerous inclusions. Inclusions of early generations are filled by LCO_2 (Tm -56.6°C, Th from +21 to 30°C), by a salt-water solution (Tm -12°C) and by LCO_2-H_2O-salt fluid (one inclusion found). Late generation inclusions bear H_2O-salt solution with Tm from 0 to -26°C. This indicates that the anorthosite pegmatites formed in a heterogeneous system, in the presence of a H_2O-LCO_2-salt fluid. Thus, the studied anorthosites formed at least 1200°C and (5.1 to 7.0) x 10^8 Pa, as indicated by the LCO_2 inclusions. (A.K.)

BERG, H.-J. and SEGALSTAD, T.V., 1989, Geochemical conditions for deposition of some hydrothermal gold deposits in Norway (abst.): Terra abstracts, v. 1, p. 25.

Three hydrothermal tectonic vein Au (+ quartz) deposits formed near the co-stability of pyrite, hematite, and magnetite with chlorite wall rock alteration: (1) Bømlo mines (W Norway) in basic rocks; (2) Bindalen mines (N Norway) in acidic rocks; (3) Lommedalen (SE Norway) in intermediate rocks. (1) has carbonates related to Au; (2) arsenopyrite; (3) hematite; (1) and (3; earlier than Au) chalcopyrite; (1) and (2) tourmaline. Fluid inclusions Th: (1) 140-160°C (saln. -5 wt % NaCl eq.; some CO_2); (2) 140-360°C (saln. 0.2-21; CO_2 rich); (3) 120-400°C (saln. 0.2-13; ave. 4). Early $CaCl_2$-rich inclusions occur at (3). Carbonates give $\delta^{13}C$ -5 to -4‰ for (1) and (2); -7 to -3 for (3; ave. -5). This precludes an organic source for the C, indicating a magmatic source. Carbonate $\delta^{18}O$ (SMOW) of 8‰ from (3) also supports a magmatic hypothesis for the hydrothermal fluids there. $\delta^{18}O$ of 17 to 17‰ for (1) and 10 to 12‰ for (2) is thought to represent predominantly magmatic water with spread due to T isotope effect. (From authors' abstract by E.R.)

BERNDT, M.E. and SEYFRIED, W.E., Jr., 1989, B, Br and other trace elements as clues to the origin of Cl variability in mid-ocean ridge vent fluids (abst.): Eos, v. 70, p. 1396.

BERNDT, M.E., SEYFRIED, W.E., Jr. and JANECKY, D.R., 1989, Plagioclase and epidote buffering of cation ratios in mid-ocean ridge hydrothermal fluids: Experimental results in and near the supercritical region: Geochim. Cosmochim. Acta, v. 53, p. 2283-2300. First author at Dept. Geology and Geophysics, Univ. Minnesota, Minneapolis, MN 55455.

Experiments have been performed with Na-Ca-K-Cl fluids of seawater chlorinity and diabase, basalt, and plagioclase bearing mineral mixtures at 350-425°C and 250-400 bars to help constrain hydrothermal alteration processes at mid-ocean ridges. Dissolved Ca, Na, and pH for all experiments responded systematically to differences in dissolved SiO_2 concentrations and the compositions of plagioclase reactants. Diabase alteration at low fluid-rock mass ratios (0.5 to 1) produces fluids undersaturated with respect to quartz during hydration of primary olivine and orthopyroxene, whereas basalt alteration under similar conditions yields fluids slightly supersaturated with respect to quartz during breakdown of glass to smectite and amphibole. Fluid chemistry in all experiments appears to approach a partial equilibrium state with the albite and anorthite components in plagioclase and approaches a pH consistent with plagioclase alteration to epidote.

Trace element data from vent fluids, specifically B and Sr, together with major element chemistry (Ca, Na, SiO_2, pH), provides evidence that the reaction zone for "black-smoker" fluids at mid-ocean ridges is composed of only slightly altered diabase and is characterized by small amounts of epidote, nearly fresh plagioclase and clinopyroxene, and partially to completely hydrated olivine and orthopyroxene. Fluids reacting with this rock may be undersaturated with respect to quartz so P estimates based on the quartz geobarometer should be regarded as minimums. Using equilibrium between plagioclase, the dominant reactant, and epidote, the dominant reaction product in experiments, we estimate that T in reaction zones are in excess of 375°C for most vent systems. These T are higher than measured vent T, suggesting that hotspring fluids commonly lose heat during ascent to the seafloor. (Authors' abstract)

BERTASI, R.D. and **BARTON, M.D.,** 1989, Phase equilibria of a high-pressure melange pegmatite: Implications for partial melting and volatile-transfer during subduction (abst.): Eos, v. 70, p. 1376.

BÉNY, C. and **GUILHAMOU, N.,** 1989, Raman microprobe analysis of organic gaseous fluid inclusions (abst.) Symposium GEORAMAN 89, Toulouse, France, 17-19 May 1989, Abstracts (unpaginated). Also in Bull. Liason Soc. Franc. Mineral. Crist., v. 2, no. 1, p. 18 (1990). First author at GIS(BRGM-CNRS), 1A rue de la Férollerie, 45071 Orleans Cedex 02, France.

Raman microspectrometry allows "in situ" analyses of non-fluorescent organic phases entrapped as fluid inclusions in minerals and identification of hydrocarbons (CH_4, C_2H_6 and C_3H_8). Accordingly, one may determine the composition of organic-rich gas phases (including N_2, CO_2, H_2S) in fluid inclusions formed during diagenetic and/or anchimetamorphic events.

Studied samples were collected from three different occurrences: the Terres Noires Jurassic shales of the prealpine basin; the Smackover formation in Perry County (Mississippi) at 6.5 km depth; and a metamorphic area in the Champsaur sandstones (southern Pelvoux). Inclusions, present in host minerals such as quartz, calcite and barytocelestite, are monophase vapor (V) or with a thin rim of liquid (L-V). Usually Th are above critical T of pure CH_4, suggesting extra components.

The identification of these components, realized by Raman microspectrometry and the calculation of their relative proportions, lead to distinguish various gaseous assemblages. Because of the relative intensities of CH_4, C_2H_6 and C_3H_8 characteristic bands, spectra accumulations have been required to improve signal/noise ratio.

In the Terres Noires (Guilhamou et al., Bull. Min., 1988, Fig. 2, p. 579), two gaseous assemblages are found: CH_4 - C_2H_6 - C_3H_8, with minor amounts of CO_2 and N_2 (wet gas); and CH_4 - CO_2 (dry gas). The wet gas is present in the western part of the basin and the dry one in the eastern one. This [difference] confirms the different thermic evolution of the two parts of the basin as evocated first by Th of the aqueous inclusions, vitrinite reflectance and illite crystallinity measurements (Touray and Guilhamou, 1988, Geologie Alpine, Memoire 14).

In contrast, a CH_4 - C_2H_6 assemblage is associated with anchimetamorphic zones in the Champsaur sandstones (southern Pelvoux) corresponding to ~200°C (prehnite crystallization T).

In the Smackover formation (Guilhamou et al., Bull. Min., 1984, Fig. 3, p. 197), trapped assemblages are made of poorly ordered carbon - CH_4 - CO_2 - H_2S in different proportions. A density reequilibration of aqueous inclusions to actual bottom hole T and P (indicated by their corrected Th) and systematic presence of carbon in gaseous inclusions suggest that mixtures initially entrapped were composed by heavier gaseous hydrocarbons. These evolved during burial to produce the actual assemblage characteristic of metagenetic processes.

These data illustrate the ability of Raman microspectrometry to analyze organic and inorganic gaseous assemblages as well as carbon residues in relation with diagenetic and anchimetamorphic processes. These assemblages were entrapped during different thermal evolution stages; they may be related to the degree of maturation of the organic matter. Particularly, the distinction between wet gas produced during catagenesis and dry gas produced during metagenesis is accurately made. (Authors' abstract)

BHADRA CHAUDHURI, J.N. and **NEWESELY, H.,** 1989, The gold-bearing quartz veins and their wall rocks around Kundrakocha, Singbhum district, Bihar, India (abst.): Terra abstracts, v. 1, p. 27-28.

Au is confined to quartz veins, which are megascopically differentiated [into] bluish grey and white, representing different generations and different sources. EPM analyses of blue quartz is indicative of the fluid inclusions enriched with K_2SO_4, CO_2 and most probably with KCl. (From authors' abstract by E.R.)

BIRCH, M.U. and **FORSTER, C.B.,** 1989, Modeling transient hydrothermal systems in mountainous terrain: Implications for genesis of epithermal ore deposits (abst.): Eos, v. 70, p. 495.

BISCHOFF, J.L. and PITZER, K.S., 1989, Liquid-vapor relations for the system NaCl-H_2O: Summary of the P-T-X surface from 300° to 500°C: Am. J. Sci., v. 289, p. 217-248. First author at U.S. Geol. Survey, Menlo Park, CA 94025.

Experimental data on the vapor-liquid equilibrium relations for the system NaCl-H_2O were compiled and compared in order to provide an improved estimate of the P-T-X surface between 300^o and 500°C, a range for which the system changes from a subcritical to critical behavior. Data for the three-phase curve (halite + liquid + vapor) and the NaCl-H_2O critical curve were evaluated, and the best fits for these extrema then were used to guide selection of best fit for isothermal plots for the vapor-liquid region in-between. Smoothing was carried out in an iterative procedure by replotting the best-fit data as isobars and then as isopleths, until an internally consistent set of data was obtained. The results are presented in table form that will have application to theoretical modelling and to the understanding of two-phase behavior in saline geothermal systems. (Authors' abstract)

BLANK, J.G., STOLPER, E.M., SHENG, Jack and EPSTEIN, Samuel, 1989, The solubility of CO_2 in rhyolitic melt at pressures to 1500 bars (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A157.

BODNAR, R.J., 1989a, Fluid inclusion evidence for the physical and chemical conditions of petroleum generation in the Miocene Monterey Formation of California, USA (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 10-11. Author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

The Miocene Monterey Formation is a fractured hydrocarbon reservoir contained in intercalated siliceous and carbonate rocks. Oil produced from the Monterey is believed to have been sourced from organic material within the Monterey Formation. The Monterey thus represents an ideal environment in which to study the conditions of petroleum generation using FI because petroleum contained within inclusions would not have been modified through extensive interaction with rocks and fluids during long migration from source to reservoir.

FI in carbonate-filled fractures that act as the principal hydrocarbon conduits in the Monterey Formation were examined. The veins contain both aqueous and hydrocarbon FI. Aqueous inclusions occur along growth zones, in isolated small groups not obviously associated with a growth feature, and along fractures. Hydrocarbon inclusions almost always occur along growth zones and are only rarely observed randomly distributed within the crystal and never along fractures. Aqueous inclusions have salinities of 2.5-5 wt % NaCl eq. and have Th(L) at ~70-95°C, with no systematic correlation of Th with location in the fracture. Three different types of hydrocarbon inclusions were recognized based on petrographic and microthermometric analysis. The oldest hydrocarbon inclusions (closest to the wall rock) were small (<5 µm), clear in plain light, fluoresced blue-green under UV illumination, and Th 55-65°C. The next youngest type were also small and clear in plain light, but fluoresced bright yellow to yellow-green under UV illumination and Th 110-130°C. The youngest inclusions were large (up to 100 µm), orange-brown in plain light and fluoresced a dull brown under UV illumination; these inclusions Th 70-95°C.

The distribution of aqueous and petroleum inclusions in fracture-filling minerals suggests continuous growth of the mineral phase from an aqueous solution of approximately sea water composition. Episodically, hydrocarbons were introduced into the fracture system and the petroleum phase adhered to the crystal surface and was trapped to form FI during subsequent crystal growth. The earliest hydrocarbons to enter the fracture system had a lower density (higher API Gravity) than later hydrocarbons introduced into the fracture system, suggesting that the composition of the petroleum being generated was evolving with time or that natural distillation processes were occurring in the reservoir. Episodic interjection of oils into the Monterey plumbing system is consistent with results of other studies which suggest that tectonic movement or high fluid P were responsible for producing high-angle fractures that allowed petroleum to be "pumped" from lower to upper portions of the Monterey Formation. (Author's abstract)

BODNAR, R.J., 1989b, Synthetic fluid inclusions: A novel technique for experimental water-rock studies: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 99-102. Author at Dept. Geological Sciences, Virginia Polytechnic Institute & State Univ., Blacksburg, VA 24061.

Synthetic fluid inclusions have been used to determine volumetric and phase equilibrium properties of fluids over a wide range of P-T-X conditions. The technique is particularly useful in the study of immiscible fluid systems and for systems which become saturated in one or more solid or fluid phases during cooling and decompression from experimental to ambient conditions. When used in conjunction with conventional experimental techniques, synthetic fluid inclusions permit determination and quantification of physical properties of fluid systems over the complete range of PTX conditions of interest to geochemists studying crustal geochemical processes. (Author's abstract)

BODNAR, R.J., BINNS, P.R. and HALL, D.L., 1989, Synthetic fluid inclusions. VI. Quantitative evaluation of the decrepitation behavior of fluid inclusions in quartz at one atmosphere confining pressure: J. Metamorphic Geol., v. 7, p. 229-242. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

The decrepitation behavior of FI in quartz at one atmosphere confining P has been evaluated using pure H_2O synthetic inclusions formed by healing fractures in natural quartz. Three different modes of non-elastic deformation, referred to as stretching, leakage or partial decrepitation, and total decrepitation have been observed. The internal P required to initiate non-elastic deformation is inversely related to inclusion size according to the equation:

$$\text{internal P (kbar)} = 4.26D^{-0.423}$$

where D is the inclusion diameter in microns. Regularly shaped inclusions require a higher internal P to initiate non-elastic deformation than do irregularly shaped inclusions of similar size. Heating inclusions through the α/β quartz inversion results in mechanical instability in the quartz crystal and leads to mass decrepitation of inclusions owing to structural mismatches generated by P gradients in the quartz around each inclusion.

Long-term heating experiments (~2 years) suggest that the internal P required to initiate non-elastic deformation does not decrease significantly with time and indicates that short-lived thermal fluctuations in natural systems should not alter the inclusion density and Th. Inclusions that do exhibit decreased density (higher Th) are, however, always accompanied by a change in shape from irregular to that of a negative crystal.

Observations of this study are consistent with elasticity theory related to fracture generation and propagation around inclusions in minerals. These results indicate that an inclusion will not be influenced by a neighboring inclusion, or other defect in the host phase, as long as the distance between the two is >2-4 diameters of the larger of the two inclusions. (Authors' abstract)

BODNAR, R.J., HALL, D.L., KNIGHT, C.L., OAKES, C.S., STERNER, S.M. and **VANKO, D.A.**, 1989, Synthetic fluid inclusions: Applications in experimental geochemistry and fluid inclusion research (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-164. First author at Virginia Polytech. Inst. & State Univ., Blacksburg, VA.

Synthetic fluid inclusions are formed by healing fractures in Brazilian quartz at known PT conditions and in the presence of fluids of known composition. Microthermometric analyses indicate that the inclusion properties (composition and density) are identical to those of the fluid present at formation conditions. This observation proves that: (1) the inclusions contain a fluid with a composition identical to that of the parent fluid from which they were trapped, (2) fluid inclusions represent constant volume systems, and (3) nothing is added to or lost from the inclusion after trapping. Synthetic fluid inclusions, therefore, contain a sample of the fluid (or fluids) present at the conditions of formation and represent "microautoclaves" which may be used to determine properties of various fluid systems over a wide range of PTX conditions. Combined with more conventional experimental technique, synthetic fluid inclusions permit PVTX properties of fluids to be determined over a much wider range of PTX conditions than has been possible in the past and provide the most reliable technique for determining phase equilibrium properties at elevated P-T conditions.

One of the most important applications of synthetic fluid inclusions is in the determination of PVT (volumetric) properties of fluids of interest to geologists. Fluid isochores are easily determined for the complete range of crustal P-T conditions using synthetic inclusions. This technique has been used to determine volumetric properties of H_2O and an aqueous solution containing 20 wt % KCl over the range 300-700°C and 1-3 kb. Comparison of results obtained for H_2O with previously published values indicates that synthetic fluid inclusions provide PVT data that are within a few percent of those obtained using conventional techniques. Similarly, critical properties (T, P, density) of H_2O-NaCl solutions and the P-T projections of the critical isochores have been determined for compositions ≤ 30 wt % NaCl.

Phase equilibria in the H_2O-NaCl system have been determined to 1000°C and 1500 bars using synthetic fluid inclusions trapped in the two-fluid-phase-field. Inclusions that trap the liquid phase contain halite dms at room T; those which trap the low salinity phase in equilibrium with the liquid are two-phase, vapor-rich inclusions at room T.

A complete range in room T phase ratios between these two end-member populations is also found; these represent inclusions which have trapped mixtures of two immiscible phases present at formation conditions. Microthermometric analysis of those inclusions which trapped only a single, homogeneous phase have been used to define phase equilibrium characteristics in the H_2O-NaCl system, based on Tm NaCl and Tm ice of high salinity and vapor-rich inclusions, respectively.

Phase equilibria in the geologically important systems H_2O-NaCl-KCl and H_2O-NaCl-$CaCl_2$ have been determined using a combination of synthetic fluid inclusion and more conventional experimental technique. By combining these various techniques, solubility relations in the complete ternary systems (from pure H_2O to the anhydrous binary) are easily obtained.

Synthetic fluid inclusions have been used to study the decrepitation behavior of inclusions during microthermometric analysis and to simulate conditions of reequilibration of natural inclusions during retrograde metamorphism. Inclusion size is the most important feature in defining when (i.e., at what internal P) a fluid inclusion will decrepitate during heating experiments. Large inclusions (>50 µm diameter) decrepitate at internal P <500 bars, whereas small inclusions (<5 µm) require >2.5 kb internal P to cause decrepitation. In order to simulate the PT path followed by inclusions during retrograde processes in regional metamorphic environments, pure H_2O fluid inclusions were trapped at 700°C and 7 kb and then reequilibrated at 700°C and various P ranging from 2-6 kb. The reequilibrated inclusions exhibit Th consistent with internal P ~500-1500 bars higher than the confining P at the P-T conditions of reequilibration. These data suggest that P-T conditions inferred from natural inclusions from regionally metamorphosed samples should be used cautiously. (Authors' abstract)

BODNAR, R.J., REYNOLDS, T.J. and KUEHN, C.A., 1985, Fluid-inclusion systematics in epithermal systems, *in* B.R. Berger and P.M. Bethke, eds., Geology and Geochemistry of Epithermal Systems: Reviews in Econ. Geol., v. 2, p. 73-97.

Petrographic and petrologic characteristics of FI trapped in the relatively near-surface epithermal environment contrast markedly with those of I trapped in deeper environments. FI in the epithermal environment typically contain only two phases at room T—a low salinity L and a low density V bubble. Dms and additional fluid phases are rare to absent in the epithermal environment.

The most common host phase for I studied from most epithermal systems is quartz, and the FI textures vary systematically in a manner that permits general thermal conditions to be predicted from petrographic features. Finely crystalline euhedral quartz crystals, botryoidal chalcedonic quartz, and coarse-grained, clear euhedral quartz crystals rarely contain FI large enough to study. Those that are present usually homogenize at ≤200°C, and necking down is common. Medium-to-coarse quartz, often exhibiting several growth zones outlined by fluid and solid I, generally provide the most reliable data from epithermal systems. The shape of FI in this type of quartz varies systematically as Th increases, with flat irregular I generally homogenizing at ~230°C, irregular but more three-dimensional I homogenizing at ~250°C, and smooth-surfaced, equant to negative crystal-shaped I homogenizing at ~270°C.

Boiling is common in the epithermal environment, and FI trapped from boiling solutions may be identified based on petrographic and microthermometric behavior. Room T phase relations may be calculated from available PVTx data for any given trapping conditions, and these may be compared with observed phase relations. Similarly, trapping of mixtures of L and V commonly occurs when FI are trapped from boiling solutions, and the expected phase and microthermometric behavior of these mixed I may be calculated from PVTx data. Example calculations are provided.

The presence of small amounts of CO_2 is common in I from the epithermal environment. The observed concentrations, ranging from a few tenths of a mole percent upwards, are similar to CO_2 concentrations in modern analogues of the epithermal deposits, the terrestrial geothermal systems. The presence of these small amounts of CO_2 is difficult to identify using petrographic and microthermometric techniques because the CO_2 generally does not form a separate L or solid CO_2 phase, even upon cooling, and any clathrate that might form is of such small amount and intergrown with ice that it cannot be detected. The presence of these relatively small and often undetectable amounts of CO_2 may significantly lower the depth at which boiling of the rising hydrothermal solution will begin, and loss of CO_2 as well as other dissolved gases can significantly affect the fluid chemistry, resulting in ore mineralization. Several sample calculations, illustrating the effect of CO_2 on depth of boiling, behavior of CO_2-bearing I during crushing, and expected room T phase relations of CO_2-bearing I are provided.

Boiling as a depositional mechanism for precious metals is an integral part of epithermal models that have been developed recently. As such, FI may be used in exploration for epithermal precious metals deposits because FI trapped from boiling solutions exhibit characteristics distinct from I trapped in the one-phase (nonboiling) environment. Thus, if FI observed in surface samples suggest trapping in the single-phase field, any (overlying) boiling zone that might have existed has since been eroded and the probability of precious metal mineralization at depth is minimal. Conversely, the presence of I indicative of trapping in a boiling environment in this same sample would suggest that the boiling horizon and, therefore, that portion of the hydrothermal system most likely to contain the highest-grade precious metal mineralization, is at some depth below the surface. (Authors' abstract)

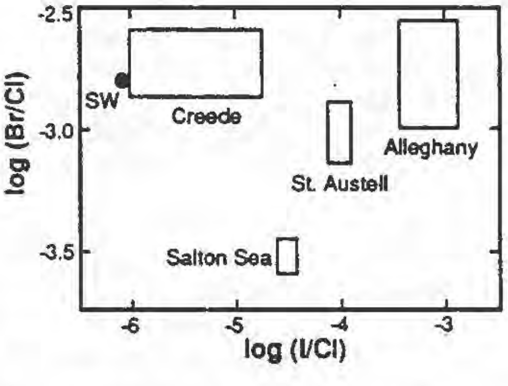
BODNAR, R.J., STERNER, S.M. and **HALL, D.L.**, 1989, Salty: A Fortran program to calculate compositions of fluid inclusions in the system NaCl-KCl-H_2O: Computers & Geosci., v. 15, no. 1, p. 19-41. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

An algorithm for estimating compositions of FI approximated by the NaCl-KCl-H_2O system has been developed using recently published data for phase equilibrium properties of vapor-saturated NaCl-KCl-H_2O solutions. The algorithm satisfactorily reproduces experimental results for all compositions in the ternary system and requires only the T of two phase changes to calculate the total salinity and the NaCl/(NaCl + KCl) weight fraction of the inclusion fluid. The required input data are the T at which the final two solid phases dissolve during heating. These data are obtainable easily during standard microthermometric analysis of the inclusions. (Authors' abstract)

BOETTCHER, S.L., GUO, Qiti and **MONTANA, Art**, 1989, A simple device for loading gases in high-pressure experiments: Am. Mineral., v. 74, p. 1383-1384.

BOHLKE, J.K. and **IRWIN, J.J.**, 1989, Halogen ratios (Cl:Br:I) in natural fluid inclusions analyzed by laser ablation and noble gas mass spectrometry (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A358. First author at U.S. Geological Survey, MS 954, Reston, VA 22092.

Halogen ratios in aqueous fluids can provide information on sources of salinity, which largely determine the physical and chemical transport properties of hydrothermal systems. Hydrothermal minerals from Creede, CO, the Salton Sea geothermal system, CA, Alleghany (Mother Lode), CA, and St. Austell (Cornwall), England, were irradiated to produce ^{38}Ar, ^{39}Ar, ^{82}Kr, and ^{128}Xe from Cl, K, Br, and I, respectively, in fluid inclusions (FI). Natural and neutron-induced Ar, Kr, and Xe isotopes wee then released from FI by laser ablation and analyzed in a noble gas mass spectrometer. The data [shown below as atomic ratios with seawater (SW) for reference] clearly indicate distinct fluid types with contrasting sources of dissolved anions.



FI in sphalerite and fluorite from polymetallic veins at Creede (1-2 m Cl) have Br/Cl and I/Cl ratios relatively near those of seawater and dilute volcanic-hosted geothermal waters, indicating that saline lakes in the postulated recharge area probably did not evaporate much beyond halite saturation and that the fluid salinity was not derived from dissolution of halite-bearing rocks. Calcite veins from the Salton Sea contain brines (4-5 m Cl) having low Br/Cl ratios, similar to those of modern production fluids and indicative of halite dissolution. Dilute CO_2-bearing FI in Au quartz veins from Alleghany (0.1-0.5 m Cl) have the highest I/Cl ratios, possibly indicating I contributions from marine organic-rich shales. High-T FI in quartz-tourmaline-topaz rock from St. Austell (3 ± m Cl) have Br/Cl and I/Cl ratios similar to those of many arc volcanic gases (possible "magmatic" halogen signature?). In addition to the major contrasts between groups of samples, significant variations in Br/Cl and I/Cl within some of the sample sets indicate evolutionary changes in the hydrothermal systems. (Authors' abstract)

See also Böhlke, J.K., in this volume. (E.R.)

BOIRON, M.C. and **CATHELINEAU, M.**, 1989, Ore fluid-rock interaction and mass transfer within Au-As-Sb mineralized shear zones: Characterization and modelling on the example of the Massif Central (France) deposits: *in*

D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 103-106. Authors at CREGU, Vandoeuvre, France.

See Boiron and Cathelineau, 1987 (Fluid Inclusion Research, v. 21, p. 41) and Boiron et al., 1988 (Fluid Inclusion Research, v. 21, p. 42). (E.R.)

BOIRON, M.C., CATHELINEAU, M., DUBESSY, J., BASTOUL, A.M. and **POTY, B.**, 1989, Fluids in Au ore deposits for the Variscan range, France (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 12-13. Authors at CREGU, BP 23, 54501 Vandoeuvre lès Nancy Cedex, France.

Fluids together with alteration and ore mineral assemblages were studied in representative hydrothermal Au veins from the western part of the Variscan belt in France (Au mines of La Belliere, Salsigne, Villeranges, Le Chatelet, and Limousin occurrences). The veins are related to the late stages of brittle deformation which affected the Variscan terranes at the end of the Hercynian orogeny. Systematic studies of FI in the gangue minerals (quartz, calcite, ankerite) of Au ores show that two different types of Au veins can be distinguished:

1. Veins showing a multistage evolution in fluid composition and ore deposition within quartz veins exhibiting complex fracturing, shearing and microcrack healing (shear zone of Brittany and Limousin). Ores (Au + sulphides) and inclusions of ore fluids occur mainly within small microcracks along which the early milky quartz recrystallized. Fluids occur either as S inclusions (healed microcracks) or P inclusions (recrystallized zones), and correspond to multistage fluid migration and trapping within the early quartz vein. Two distinct stages have been recognized:

(i) CO_2-CH_4-H_2S-N_2 (±H_2O-NaCl) rich fluids trapped at relatively high T (250-450°C) and P (0.8-2.5 kb), related to the early sulphide (±native Au) deposition. The highly variable water content of the inclusions has been related to the location of the FI in the time/space sequence of fluid trapping in the quartz vein. Its origin is discussed in the light of the different models of mixing, unmixing or boiling which may be considered for such compositional variations.

(ii) Aqueous fluids (H_2O-NaCl) having low salinity (1-4 wt % NaCl eq.) trapped at lower T (150-250°C) during later brittle deformation stages. They are partly related to the late native Au-sulphide assemblage, which constitutes the economic ores in some deposits.

2. Veins characterized by almost pure aqueous fluids (H_2O-NaCl) having a low salinity (1-4 wt % NaCl eq.). Fluids are observed as P FI in the quartz combs bearing the Au-rich sulphides (arsenopyrite and pyrite, at Villeranges, and Le Chatelet). Trapping T are in the range 150-250°C, and P are considered to be nearly hydrostatic.

Consideration of chemical equilibria in the C-O-H-S system using microthermometric and Raman spectrometry data on fluids, together with data obtained from mineralogical studies, indicate that during Au deposition fO_2 was rather low, being below the hematite-magnetite buffer value at Villeranges, around that fixed by the Ni-NiO oxygen buffer at Salsigne and at La Belliere. fS_2 was relatively high (pyrrhotite unstable, close to that fixed by the pyrite-pyrrhotite boundary) and pH significantly lower along the hydrothermal channels than in the host rocks, as shown by the complete alteration of wall rocks into a quartz-K-mica assemblage. Such data about physical-chemical conditions are used to constrain the models for Au deposition. (Authors' abstract)

BOIRON, M.C., CATHELINEAU, M., DUBESSY, J., KIBONZI, B., TOLLON, F. and **NORMAND, M.**, 1989, Physical and chemical conditions of gold deposition in quartz veins from the Montagne Noire 'Schistes X', Salsigne gold districts, France (abst.): Terra abstracts, v. 1, p. 28.

The Salsigne district includes three major stages: an early Au concentration as massive sulphide layers, interpreted to have a sedimentary-exhalative origin; a strong plastic deformation of the early ores during late Paleozoic events; a brittle deformation stage yielding to numerous mineralized quartz veins. A significant fluid circulation occurred during the microfracturing of these quartz veins and caused a remobilization of the early Au concentrations. Au is frequently associated with the sulphides (mostly arsenopyrite). The early milky quartz is almost completely recrystallized in the vicinity of the mineralized microcracks and occurs in some cases as euhedral quartz grains.

A systematic study of fluid inclusions has been carried out in early and recrystallized quartz. The recrystallized quartz is characterized by the close association of carbonic and aqueous fluids: (1) CO_2-CH_4-N_2, H_2S (±H_2O, NaCl) rich fluids, with a variable H_2O amount, and Th ranging from 250 to 320°C; (2) H_2O-NaCl fluids, having low salinity (1-2 wt % eq. NaCl), with Th ranging from 200 to 280°C.

Data of fluids (microthermometry and Raman spectroscopy) and mineral assemblages indicated that during Au deposition fO_2 was around that fixed by the Ni-NiO oxygen buffer ($10^{-30(\pm 1)}$) at the estimated Tt of 350°C, fS_2 was relatively high ~$10^{10\pm 1}$ [sic] and not very far from that fixed by pyrite-pyrrhotite boundary, and the minimal P was in the range 1.5-2.0 kbars. The model of Au deposition and the changes in the fluid chemistry (unmixing or not?) are discussed from the global reconstruction of the P-T conditions. (From authors' abstract by E.R.)

BOIRON, M.C., CATHELINEAU, Michel and TRESCASES, J-J., 1989, Conditions of gold-bearing arsenopyrite crystallization in the Villeranges basin, Marche-Combrailles shear zone, France: A mineralogical and fluid inclusion study: Econ. Geol., v. 84, p. 1340-1362. First author at Centre de Recherches sur la Géologie de l'Uranium, PB 23, 54501 Vandoeuvre-les Nancy Cedex, France and Laboratorie de Pétrologie de la Surface, 40 Avenue du Recteur Pineau, 86022 Poitiers Cedex, France.

The Au-As-Sb deposits from the Marche-Combrailles (northwestern part of the French massif Central district) are spatially associated to the Marche-Combrailles shear zone. Host rocks are either Visean volcano-sedimentary tuffs or formations of the Paleozoic basement presenting a greenschist facies assemblage which resulted from extended hydrothermal metamorphism. Solubilization, transport, and deposition of Au, As, and Sb occurred together with specific rock alteration along faulted zones on distances ranging from several centimeters to a few decimeters. Wall rocks are affected by complete bleaching resulting from chlorite replacement by phengite (T = 240° ± 30°C) followed by complete replacement of the previous minerals by an illite-quartz-ankerite-pyrite assemblage. Au is carried in a combined state with arsenopyrite, occurring either within a diffuse network of quartz + ankerite veinlets or as isolated crystals in the altered tuff. Mass balance calculations on fresh and altered rocks show that during the ore stage, hydrothermal fluids contributed H_2O, CO_2, and S (Au, Sb) to authigenic minerals and leached almost completely Na, Ba, Sr. Ore fluids are characterized by an aqueous composition, a rather low salinity, and T (160° to 200°C). Ore deposition occurred at a low pH, indicated by the complete alteration of the host rocks into a quartz-illite association, and at a low fO_2 intermediate between the fO_2 fixed by the hematite-magnetite and Ni-NiO oxygen buffers. Au deposition probably resulted from a destabilization of Au bisulfide or thioarsenide complexes during the sulfide crystallization. Thus, the Au-As-Sb ores in the Villeranges area result from a single hydrothermal stage and occur during a late stage of brittle deformation, significantly posterior to the continental basin formation and the acid volcanism. Ore fluid circulation is linked mostly to the fluid convection produced by the abnormal heat flow characterizing the Marche-Combrailles shear zone. (From authors' abstract by E.R.)

BONE, Yvonne, 1989, Paleothermal analysis by fluid inclusions: Hydrocarbon exploration strategies in the Cooper/Eromanga Basins, Australia (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 11. Author at Dept. Geol. and Geophys., Univ. Adelaide, Australia.

Over the last decade a number of studies concerning the thermal history of Australia's most productive onshore hydrocarbon province, the Cooper and overlying Eromanga Basins, have been made. These have largely concentrated on extrapolations to maximum T, from either the determination of organic maturation levels, derived from the mean average reflectance in oil ($Rm_o\%$) of vitrinite, or from corrected bottom hole T (BHT).

Direct paleotemperature information can be obtained by the use of FI microthermometry, using the very small (≤2 μm) FI entrapped within cements, overgrowths and veins associated with the detrital siliciclastics.

Sediments are immediately, and continuously, subjected to diagenetic effects upon burial. These can include the precipitation of carbonate cements or silica overgrowths, which lead to porosity occlusion; or the dissolution of these or the earlier P components, leading to the development of S porosity. Silica overgrowths have been the dominant destroyer of P porosity in the Cooper/Eromanga Basins.

Cathodoluminescence (CL) studies have allowed the timing of this overgrowth development, whilst identical CL signature from the silica that has healed intragranular fractures suggests that these two events were coeval. Under UV fluorescence microscopy some of the FI present within the healed fractures and the silica overgrowths ("thin skin FI") fluoresce, indicating that the fluid contains hydrocarbons.

Th obtained from the FI within Cooper Basin samples, when plotted against $Rm_o\%$ on a semi-logarithmic plot, define a slope that is indicative of significant cooling when compared to published maximum T. The overlying Eromanga Basin samples define a slope that is similar to maximum reflectance derived trends. This suggests that Cooper Basin section was subjected to considerable erosion at the end of the Triassic, prior to the deposition of the

Eromanga Basin sequence. This is supported by other geological evidence. In contrast, the Eromanga Basin rocks do not appear to have cooled significantly since entrapment of the FI, i.e., since silicification. Reference to subsidence curves (based on Rm_o% and BHT values and stratigraphic ages) suggest that this event occurred ~100 Ma. Th values vs. depth defines a straight line, and provides geothermal gradients marginally higher than BHT values.

It is the explanations for these similarities and discrepancies that has enabled the development of new strategies for further hydrocarbon exploration in the Cooper and Eromanga Basins. (Author's abstract)

BONI, M., RANKIN, A.H. and SALVADORI, M., 1989, Fluid inclusion evidence for the evolution of skarn and associated Zn-Pb-Cu-CaF_2 mineralization in S.W. Sardinia, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 14. First author at Dipart. di Sci. della Terra, Univ. di Napoli, Napoli, Italy.

Skarn-hosted mineralization comprising Fe, Zn, Pb, Cu sulphides, fluorite and barite occurs throughout SW Sardinia. These exoskarns may be subdivided into metamorphic and vein type. Both are hosted within Cambro-Ordovician sediments intruded by post tectonic, Hercynian leucogranites. Paragenetically, the mineralization postdates the development of typical skarn minerals. Garnets, clinopyroxenes and wollastonite are replaced by later generations of garnet, amphiboles, epidotes and finally chlorites.

FI are poorly developed in the earliest skarn minerals. Microthermometric measurements were restricted to two-phase L+V aqueous inclusions in late stage garnets (Th 225-325°C) and vein skarn hedenbergite (Th 250-400°C). Tm ice in both cases ranged from -5 to -1.7°C. Inclusions in epidote had Th over a comparable T range (280-330°C). These inclusions represent the earliest detectable, pre-ore *stage 1a* fluid.

A fluid of slightly different composition (almost pure water) is represented by large P aqueous inclusions in early, disseminated fluorite crystal in vein skarn (*stage 1b* fluid). These showed Th L typically in the range 260-370°C and Tm ice ~-0.1°C. Unidentified, rectangular dms are characteristically present but fail to dissolve completely on heating. Inclusions with comparable high Tm ice (-0.1°C) but lower Th (170-270°C) are developed in quartz coeval with sphalerite afflicted by "chalcopyrite disease."

A late-stage, low T fluid is recorded by aqueous inclusions in calcite and late fluorite (*stage 2* fluid phase). These have Th between 88 and 120°C, Te < -50°C and Tm ice between -32 and -26°C. The high salinities, high Ca contents and low T interpreted from these microthermometric results are closely comparable to published FI data on discrete paleokarst Pb-CaF_2-$BaSO_4$ mineralizations in the same area.

In conclusion, the FI data support the paragenetic evidence of an evolving skarn process and superimposed mineralization involving fluids of different compositions and origins. (Authors' abstract)

BOTTRELL, Simon, 1989, Gold transport and precipitation in black shale hosted vein gold deposits in North Wales: Evidence from sulphur volatiles in fluid inclusions (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 27. Author at Dept. Earth Sciences, The University of Leeds, Leeds LS2 9JT, U.K.

Abstract same as by Brand et al., 1989, this volume. (E.R.)

BOTTRELL, S.H., BRAND, N. and MILLER, M.F., 1989, Analytical evidence for sulphur species as gold ligands in metamorphic fluids (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 15. First author at Dept. Earth Sci., Univ. Leeds, Leeds, LS2 9JT, UK.

A technique has been developed for the analysis of reduced S species in inclusion volatiles. The volatiles are released by decrepitation of inclusions in a N_2 stream and the S gases trapped in NaOH solution. The total yield of reduced S species (essentially H_2S and COS) is then analyzed fluorometrically. Other inclusion volatiles (H_2O, CO_2, CH_4, N_2, Ar and H_2) were analyzed by decrepitation under vacuum and a combination of manometry and mass spectrometry, thus enabling the calculation of reduced S concentration in the inclusion volatiles.

We have analyzed reduced S concentrations in FI in metamorphic veins, Au mineralized and unmineralized "feeder" veins from the Cambrian "Harlech Dome" in N. Wales. Au mineralization here is thought to result from reaction between relatively oxidized metamorphic fluids (which migrated in response to tectonic uplift) and graphitic black shales. Thus Au was transported by the metamorphic fluids. Comparison of the Au transport potential of chloride (determined by microthermometry) and sulphide complexes shows that these fluids could transport up to 10 ppm Au as $Au(HS)_2^-$ but less than 0.001 ppm Au as $AuCl_2^-$, demonstrating that sulphide complexes are the major Au transporting agents in these solutions. Data on reduced S and other volatiles in quartz from the auriferous veins are used to elucidate the chemical controls on destablization of the Au(HS)$_2^-$ complex during the mineralizing process. (Authors' abstract)

BOTTRELL, S.H. and **MILLER, M.F.**, 1989, Analysis of reduced sulfur species in inclusion fluids: Econ. Geol., v. 84, p. 940-945. First author at Dept. Earth Sciences, Univ. Leeds, Leeds LS2 9JT, U.K.

A method for the determination of reduced sulfur species in inclusion fluids is described. Inclusion fluids are released by decrepitation in a N_2 stream, the sulfur species are trapped in a 0.1 *M* NaOH solution and subsequently determined fluorometrically. Method blanks are low (ca. 3 ng S) compared to yields from vein quartz samples (80-6,700 ng S); the detection limit for reduced S is effectively set by this blank and corresponds to ca. 20 ppm S in the original inclusion fluid for a typical 0.5- g sample yielding a total of 1 mg of volatiles. The method is sensitive to S present as H_2S or COS but not CS_2 or SO_2.

Analyses of inclusion fluids from unmineralized feeder veins in the Dolgellau Au belt, north Wales, indicate that Au $(HS)_2^-$ predominated over $AuCl_2^-$ as the major Au-transporting complex. (Authors' abstract)

BOTTRELL, S.H. and **YARDLEY, B.W.D.**, 1989, Metamorphic and post-metamorphic fluids in low grade rocks, North Wales, UK (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 16. Author at Dept. Earth Sci., Univ. Leeds, Leeds, LS2 9JT, UK.

Microthermometric and volatile (H_2O, CO_2, CH_4, N_2, Ar, H_2) analysis has been used to study inclusions in metamorphic and post-metamorphic veins in low grade metasediments in the Harlech Dome, N. Wales. This combination of data has allowed us to determine the chemical and physical properties of the fluids present during and after metamorphism and to estimate the P-T conditions under which these fluids were trapped. By combining this with stable isotope and geochemical data we have been able to construct the following model of fluid behavior during and after metamorphism:

At the metamorphic peak, low to moderately saline Na-K-Cl brines were present in most of the sequence except in graphitic units where a pair of immiscible CH_4-H_2O fluids were present. At this time, there was restricted movement of fluid between different lithological units.

Soon after the metamorphic peak, there was a phase of relatively rapid uplift (P in the Clogau Fm. shales dropped from c.3 to c.1.8 kb while T dropped from c.350°C to c.320°C). In response to this change, metamorphic fluids migrated up through the sequence resulting in the formation of Au mineralized quartz veins in black shale units. Mineralization was the result of reaction between aqueous metamorphic fluids and graphite in these units, generating an immiscible CH_4-rich phase.

Two inclusion types were trapped subsequent to this event; moderately to highly saline calcic brines and weakly saline fluids. These are present throughout the sequence and may be responsible for the resetting of oxygen isotopic compositions of some minerals. (Authors' abstract)

BOULLIER, A-M., MICHOT, Gérard, PECHER, Arnaud and **BARRES, Odile**, 1989, Diffusion and/or plastic deformation around fluid inclusions in synthetic quartz: New investigations, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 345-360. First author at Centre de Recherches Pétrographiques et Géochimiques, B.P. 20, 54501 Vandoeuvre-lès-Nancy, France.

Synthetic quartz containing fluid inclusions (H_2O + NaOH, 0.5 N) was annealed at high T (T = 448°C) and under confining P (P_c = 200 or 350 MPa). Changes in the shape of the inclusions were observed together with variations of their filling densities which depend on the value of the internal P, P_i; the latter tends to equilibrate with the confining P, P_c, either by decrepitation or by progressive evolution. X-ray topography after treatment reveals contrast around the modified fluid inclusions. T.E.M. investigations show some dislocations around the inclusions after experiment. However, IR microspectroscopy does not show any visible change in the water absorption band in samples before and after annealing.

These results are discussed and some interpretations are proposed. As demonstrated by previous authors (Gratier and Jenatton, 1984), the changes in the shape are due to solution-deposition processes. Plastic deformation around fluid inclusions is probably largely responsible for the changes in density, but diffusion processes (positive and negative exchanges between quartz and fluid inclusions) cannot be entirely excluded. The driving force may be the elastic strain energy due to the difference in P between the fluid inclusion and the confining medium (Doukhan and Trépied, 1985). (Authors' abstract)

BOWERS, T.S., 1989, Stable isotope signatures of water-rock interaction in mid-ocean ridge hydrothermal systems: Sulfur, oxygen, and hydrogen: J. Geophys. Res., v. 94, no. B5, p. 5775-5786. Author at Dept. Earth, Atmosp. and Planet. Sci., Massachusetts Inst. Tech., Cambridge, MA.

Reaction path models of sea water-basalt interaction at mid-ocean ridges similar to those presented by Bowers and Taylor (1985) are extended to include sulfur isotopic exchange equilibria. The effects of variable contribution of sulfur from basalt and of high- and low-T reduction of sulfate in the fluid are considered. Results of the model calculations are compared with $\delta^{34}S$ analyses of disseminated sulfides in altered basalts, chimney sulfides, and fluids collected from mid-ocean ridge hot springs. The calculations indicate that under the physical conditions of water-rock interaction in mid-ocean ridge circulation systems, the overwhelming influence on the sulfur isotope signature of exiting fluids is basaltic sulfur. No trace of $\delta^{34}S$ enrichment by reduction of sea water sulfate is recorded in hot spring fluids unless the reduction occurs at high T (350°C) or near the venting areas. A comparison of recent O and H isotope data from several vent sites suggests that contributions of altered basalt and fluid with a significant history of low-T interaction with basalt can be qualitatively assessed. (Author's abstract)

BOWMAN, J.R. and **COOK, S.J.**, 1989, Influence of pathlength and rate of exchange on isotopic evolution in hydrothermal flow systems: Implications to isotope exchange profiles and water(w)/rock(r) ratios (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A84.

BOZKURT, Umur, 1989, A fluid inclusion study of selected boreholes, Salton Sea geothermal system, Imperial Valley, California: M.S. thesis, Univ. California, Riverside, CA, 208 pp.

This report is based on an investigation of fluid inclusions in drill cutting samples recovered from the IW-1, IW-2, IW-6 and Elmore #4 wells in the Salton Sea Geothermal System (SSGS), Imperial Valley, California. These wells were all drilled in the central part of the system, with the IW wells being located slightly closer to center of the thermal anomaly. The cuttings collected from the Elmore #4 well indicate that fluids that existed in this region caused much more extensive hydrothermal alteration and mineralization than those that existed in the region of IW wells.

Fluid inclusion analyses for the 335-447 m intervals of the IW-1 and IW-2 wells indicate that the salinities of vein fluids varied between 1.6 to 15.4 wt % NaCl eq. over a Th range from 131.0 to 252.0°C. In the IW-1 and IW-6 wells at 843-1047 m the observed ranges of these parameters are 12.9-26.0 wt % NaCl eq. and 272.5-313.5°C, respectively. Measurements taken from the Elmore #4 well at 1143-1478 m show variations between 19.1-28.1 wt % NaCl eq. and 224.9-347.0°C.

The salinity changes in fluids trapped in (evaporitic) anhydrite and vein calcite from the IW-6 well (900 and 957 m) imply that dissolution of evaporites under reservoir conditions has contributed to salinity of the SSGS brine. A halite-bearing calcite crystal observed at 1241 m depth of the Elmore #4 well indicates that solid NaCl apparently existed at this depth and could have added to high salinities determined from this well. The Th values for certain intervals of the IW-1, IW-2 and Elmore #4 wells imply that fluids hotter than current T have existed in the past. Th values for some sample depths of the Elmore #4 well fall as much as 37.6°C lower than the logged T, and thus indicate heating of this portion of the system after trapping.

The NaCl/($CaCl_2$ eq.) weight ratios of the inclusions from the Elmore #4 well are in good agreement with that of the brine produced from this well, indicating that the ternary diagram for the system H_2O-NaCl-$CaCl_2$ is applicable to fluid inclusion studies concerning brine types as complex as those from the SSGS. (Author's abstract)

BÖHLKE, J.K., 1989, Comparison of metasomatic reactions between a common CO_2-rich vein fluid and diverse wall rocks: Intensive variables, mass transfers, and Au mineralization at Alleghany, California: Econ. Geol., v. 84, p. 291-327. Author at U.S. Geol. Survey, Nat'l Center, MS 954, Reston, VA 22092.

The Au deposits at Alleghany, California, are typical of many epigenetic Au-bearing hydrothermal vein systems in metamorphic terranes worldwide. Detailed analyses of alteration halos in serpentinite, mafic amphibolite, and granite wall rocks at Alleghany indicate that widely contrasting deposit types, ranging from fuchsite-carbonate schists to pyrite-albitites, resulted when different wall rocks interacted with the same externally derived CO_2-rich hydrothermal vein fluid. Patterns of element redistribution within halos and among lithologic units suggest a complex process involving fluid flow along vein fractures and diffusion (±infiltration) normal to the veins. Wall rocks locally controlled both the directions and magnitudes of chemical fluxes across vein walls.

It is proposed that the CO_2-rich vein fluids approached partial equilibrium with alteration assemblages in the average, or dominant, rocks along their flow paths. Simpler, but radically different, proximal assemblages were then produced where the fluids encountered chemically extreme rock types. Fluid-rock interaction equilibria can account for much of the diversity in the mineralogy and chemistry of Au deposits in heterogeneous metamorphic terranes, while maintaining a simple genetic classification based on the distinctive chemistry of the hydrothermal fluids. Comparative studies of multicomponent phase equilibria and mass exchanges can provide both rationalizations and predictions of local wall-rock effects on geochemical anomalies and the locations of ore deposits in lithologically heterogeneous terranes. Simultaneous consideration of contrasting high-variance (phase-deficient) assemblages along discordant veins is suggests as a general method for quantifying fluid-intensive variables in metasomatic systems. (From authors' abstract by E.R.)

See also Bohlke. (E.R.)

BÖHLKE, J.K., KIRSCHBAUM, C. and **IRWIN, J.**, 1989, Simultaneous analyses of noble-gas isotopes and halogens in fluid inclusions in neutron-irradiated quartz veins by use of a laser-microprobe noble-gas mass spectrometer, *in* W.C. Shanks III and R.E. Criss (eds.), New Frontiers in Stable Isotopic Research: Laser Probes, Ion Probes, and Small-Sample Analysis: U.S. Geol. Surv. Bull. 1890, p. 61-88. First author at U.S. Geological Survey, National Center, MS 954, Reston, VA 22092.

Simultaneous analyses of halogens and noble-gas isotopes in preselected fluid inclusions in minerals can provide unique information useful for (1) defining and delineating fluid reservoirs in ancient hydrothermal and metamorphic systems, (2) determining the sources of fluids and dissolved salts and determining some characteristics of rocks along fluid flow paths, and (3) documenting and quantifying mixing, boiling, and (or) unmixing of fluids in relation to mineral precipitation. In this study, a high-sensitivity noble-gas mass spectrometer combined with a laser sampler was adapted to analyze natural and neutron-induced Ar, Kr, and Xe isotopes releaseed from fluid inclusions in minerals. Mineral samples were neutron irradiated prior to analysis to produce Ar, Kr, and Xe isotopes from Cl, K, Ca, Se, Br, Te, I, Ba, and U. Preliminary results indicate that natural abundances of Ar, Kr, and Xe isotopes, as well as products of Cl, K, Br, and I, can be measured simultaneously in less than 10^{-9} liter [i.e., ~$(100\ \mu m)^3$] of dilute fluid released from hydrothermal quartz by laser decrepitation.

Aqueous fluid inclusions in Cretaceous vein quartz from Alleghany, in the Sierra Nevada, California, contain variable amounts of CO_2 (<1 to 6 molal) and small amounts of chlorine (≤0.2 molal). Fluid inclusions having intermediate CO_2 contents in three vug quartz chips from the Oriental mine have several similarities to high-T meteoric geothermal ground waters: atmospheric isotope ratios of Kr and Xe, moderately elevated $^{40}Ar/^{36}Ar$ ratios (~345-535), and absolute ^{36}Ar concentrations between ~25 and 100% of air-saturated water values. These data are consistent with at least two interpretations of the origin of Au quartz veins: (1) the veins formed from ascending dilute fluids that originated at the Earth's surface, equilibrated with air, and subsequently acquired CO_2 at greater depths in the crust either by participating in prograde metamorphic reactions or by dissolving deep magmatic gas fluxes or (2) the veins formed within a broad zone of mixing between ascending magmatic or metamorphic fluids and descending meteoric waters, such that neither endmember is represented by the analyzed samples. Fluid inclusions in two other quartz chips yield linear arrays (mixing lines?) in plots of $^{132}Xe/^{36}Ar$, $^{84}Kr/^{36}Ar$, and $Cl/^{36}Ar$ between (1) a Cl-bearing component relatively enriched in the heavier noble gases and (2) a Cl-free component relatively enriched in Ar. These data, mostly from milky microfractured quartz, may indicate either that (1) mixtures of two fluid types (vapor + liquid?) were trapped as fluid inclusions or (2) milky quartz contains large amounts of contaminant gases.

All of the Alleghany fluid inclusions have high I/Cl ratios (~10^3 times seawater), and many appear to be relatively enriched in Xe, possibly because the fluids acquired I and Xe from organic-rich marine sedimentary rocks along flow paths. The Cl concentrations of the fluid inclusions are significantly less than that of seawater, and the Br/Cl ratios are typical of low-salinity ground waters that have not interacted with strongly fractionated residual evaporite brines or salt deposits. Absence of significant marine and evaporitic salt sources within the metamorphic belt may be partly responsible for some of the chemical transport properties of the Cretaceous hydrothermal system that have led to Au ore deposition. (Authors' abstract) (Continued)

See also Irwin et al. and Bohlke and Irwin, this volume. (E.R.)

BRADSHAW, J.Y., 1989, Early Cretaceous vein-related garnet granulite in Fiordland, southwest New Zealand: A case for infiltration of mantle-derived CO_2-rich fluids: J. Geol., v. 97, p. 697-717. Author at Geology Dept., Univ. Otago, Dunedin, New Zealand.

Regionally extensive two-pyroxene granulite facies orthogneisses of Early Cretaceous age in Fiordland, southwest New Zealand, are criss-crossed by garnet-bearing feldspathic veins (and dikes) having associated marginal reaction zones of garnet granulite. The two-pyroxene granulites resulted from fluid-absent metamorphism of a suite of synkinematic primary anhydrous intrusions. Subsequent restricted formation of garnet granulite in feldspathic compositions, and locally eclogite in ultramafic compositions, proceeded chiefly via reactions involving hornblende breakdown, and occurred in response to sharply increased load P and local lowering of water activity. The restricted occurrence of carbonate scapolite and CO_2-rich FI in the vein areas suggests that water activity was lowered by infiltrating carbonic fluids. Infiltration occurred along pre-existing fracture systems, many of which were already filled with plagioclase-rich veins and dikes. Published C isotope data for CO_2 in scapolite within the veins indicates a mantle source. Open system behavior accompanying infiltration favored garnet stability by lowering bulk rock ferric/ferrous ratio and Na_2O content. Fluid infiltration occurred at or near peak metamorphic P (~12 kbar at 650-700°C). Granulite metamorphism was of short duration (<20 m.y.) and accompanied tectonic thickening in a subduction-related magmatic arc. (Author's abstract)

BRAKE, S.S., 1989, Fluid inclusion and trace element study of the Comstock District, Nevada: PhD dissertation, Colorado School of Mines.

BRAND, N.W., BOTTRELL, S.H. and MILLER, M.F., 1989, Concentrations of reduced sulphur in inclusion fluids associated with black shale hosted quartz vein gold deposits: Implications for mechanisms of transport and deposition of gold and a possible exploration tool: Applied Geochem., v. 4, p. 483-491. First author at Exploration Div., Western Mining Corp. Ltd., P.O. Box 71, Kalgoorlie 6430, W.A., Australia.

Analyses of reduced S and other inclusion volatiles in vein quartz from the black shale hosted Clogau-St. Davids Au deposit (N. Wales) show a relation exists between elevated inclusion S content and Au grade. This relation is better at discriminating between high and low grade vein material than criteria based on the other inclusion volatiles. Analyses of material from a similar but subeconomic vein system yields a small number of samples with an "auriferous signature" on the basis of either S^{2-} content or CO_2/CH_4 ratio, but application of both criteria would reject all samples.

The concentration of reduced S species in metamorphic fluids thought to have transported Au suggests that $Au(HS)_2^-$ was the dominant Au complex; thermodynamic calculations indicate that up to 8 mg Au/kg H_2O may have been transported in this manner. Gold precipitation in the ore body resulted from destabilisation of the $Au(HS)_2^-$ complex, probably either through reduction by the black shales or as a result of "flashing" of H_2S into the CH_4-rich phase which was generated during the mineralising event. (Authors' abstract)

BRANNON, J.C., PODOSEK, F.A., VIETS, J., LEACH, D., GOLDHABER, M. and ROWAN, L., 1989, Strontium isotopic tracer for ore-forming fluids in the Viburnum Trend, SE Missouri (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A3. First author at Dept. Earth and Planetary Sciences, Washington Univ., Campus Box 1169, St. Louis, MO 63130.

Application of $^{87}Sr/^{86}Sr$ as an indicator of fluid provenance for Mississippi Valley Type mineralization has been primarily in carbonates, rather than other minerals, notably sulfides, with very low Sr concentrations. We have used pulse-counting techniques to study Sr isotopic compositions in such minerals, and in their fluid inclusions, from the Viburnum Trend: mainstage octahedral galena from Mine No. 29, late-stage chalcopyrite from the Sweetwater Mine, and late-stage quartz from the Magmont Mine.

Fluid inclusions in large (several gram) samples were thermally decrepitated and then washed with water for analysis of fluid inclusion solutes. Parts of the remaining solids were then dissolved and analyzed as well. In addition to $^{87}Sr/^{86}Sr$, concentrations of Sr, Rb, K and Ca were determined by isotope dilution. Fluid inclusion $^{87}Sr/^{86}Sr$

ratios are significantly variable, ranging from 0.7091 to 0.7100. These ratios are closer to those reported for the host Bonneterre dolomite than to those of other plausible fluid sources or aquifers, suggesting that local interaction with the Bonneterre dominated at least the Sr in the fluids. They are nevertheless significantly higher than those known for the Bonneterre, and so indicate influence of a more radiogenic source such as the underlying Lamotte sandstone; these fluid compositions are not nearly as radiogenic as the Lamotte is expected to be, however, and so raise questions about prior suggestions of Lamotte-dominated fluids for main stage ore deposition (octahedral galena).

The solid minerals characteristically contain more radiogenic Sr than their fluid inclusions. This may indicate that recoverable fluid inclusions are not representative of the fluids from which the minerals actually formed. Dissolution of sulfides leaves silicate residues, however, which may be detrital. It is not clear whether analysis of Sr in these bulk sulfides yields mineral-forming fluid Sr compositions free of detrital contaminant Sr; pending resolution of this point the significance of the bulk mineral Sr compositions should be considered questionable. (Authors' abstract)

BRANTLEY, S.L., FISHER, Don and ENGELDER, Terry, 1989, Calculated rates of formation of syntectonic quartz pressure shadows and quartz veins (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A143. Authors at Dept. Geosciences, Penn. State Univ., University Park, PA 16802.

Published data concerning rates of dissolution and precipitation of quartz from aqueous solutions under hydrothermal conditions can be used to constrain the rates of formation of veins and P shadows. We have analyzed three general types of syntectonic quartz crystals (Fisher et al., this issue). Type I crystals are displacement-controlled (DC) fibers in P shadows, which we interpret to indicate growth which occurred without loss of grain boundary cohesion. Type II crystals exhibit face-controlled (FC) growth and crack-seal morphology. These textures suggest growth into a bulk fluid-filled crack which is intermittently open. Type III crystals exhibit FC-growth with large euhedrally-shaped crystals, suggesting growth into a fluid-filled crack which remained open for the entire period of growth.

At 250°C, we can use published quartz precipitation data to show that growth of Type I crystals is probably rate-limited by diffusion, rather than interface processes. Growth of type II and III crystals, however, are limited by the interface kinetics. Due to the low solubility of quartz, a single pulse of fluid into a newly-opened fracture cannot explain the observed volume of quartz precipitation. For example, deposition of 10 μ (≃ spacing of inclusion bands) of quartz in a crack-seal vein would necessitate a total crack opening of at least 100 cm ($\Delta P = 100$ b). Either advection or pore fluid diffusion must transport the quartz to the fracture surface. Based on model calculations, we can estimate that veins with Type II crystals are only open intermittently for periods of 10^0 to 10^1 years (given observed inclusion spacings of 10 μ), while type III crystals are open for periods of 10^3 to 10^4 years (given observed crystal lengths on the order of 1 cm). These calculations suggest that the fluid conduits have different timescales over which they contain fluid and allow fluid flow. P shadows with type I crystals do not involve infiltration of bulk fluid into the growth interface. Fractures with type II crystals allow intermittent fluid flow into the longer-lived type III fractures. (Authors' abstract)

BRANTLEY, S.L. and VOIGT, D., 1989a, Fluids in metamorphic rocks: Effects of fluid chemistry on quartz microcrack healing: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 113-116. Authors at Pennsylvania State Univ., University Park, PA.

See Brantley, 1988 (Fluid Inclusion Research, v. 21, p. 51). (E.R.)

BRANTLEY, S.L. and VOIGT, D., 1989b, Fluid chemistry and microcrack healing in quartz (abst.): Eos, v. 70, p. 502. Authors at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802.

Recent reports of large fluid-rock ratios recorded in metamorphic rocks (e.g., Ferry 1986) raise interesting questions as to the physical interaction of fluid and hot rock. The physico-chemical processes controlling porosity, permeability, and fluid flow in rocks are still not well understood, and the rates of these processes are very poorly constrained.

Laboratory experiments show that healing of microcracks in quartz occurs rapidly at elevated T and fluid P (a 100 micron-long microcrack will heal completely in water at 600°C and P(fluid) = P(total) = 200 MPa). Fast healing rates imply that microcracks will only remain open intermittently during metamorphism. To determine what factors could decrease healing rates and cause longer lifetimes for open microcracks, we have tested the effect of varying fluid

P, NaCl concentration, and X(CO_2). In quartz-water experiments at 500°C, 150 and 200 MPa P (P(fluid) = P(total)), increased P accelerated healing. In experiments at 400°C and 200 MPa, the presence of CO_2 decelerated healing. In all cases, T accelerated healing.

These experiments suggest that open microcracks in quartz buried in regimes where P(fluid) = P(total) will have shorter lifetimes at greater burial depths. Dunning, et al. (1984) has suggested that increased NaCl concentration also promotes microfracture in quartz by stress corrosion. These observations suggest that NaCl-brines may promote microfracture in quartzites; however, these microcracks will heal up more quickly than pure water-filled cracks. In contrast, microcracks in quartzites infiltrated by CO_2-H_2O fluids will remain open longer than microcracks in quartz-H_2O systems. (Authors' abstract)

BRATSCH, S.G., 1989, Standard electrode potentials and temperature coefficients in water at 298.15 K: J. Phys. Chem. Ref. Data, v. 18, no. 1, p. 1021.

BRAY, C.J. and **SPOONER, E.T.C.**, 1989, Fluid inclusion volatile analysis using heated crushing (~105°C)/gas chromatography with in-series photoionization/thermal conductivity detectors and digital peak processing (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 12-13. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

FI contents are released by a heated (~105°C), 1.9 cm (i.d.), stainless steel (#316) crushing system (modified from Andrawes and Gibson, 1979, Am. Mineral. 64, 453-463) connected directly to the inlet of a HP 5890 gas chromatograph (GC). This procedure ensures instant volatilization of FI contents (T > H_2O b.pt.) so that GC peaks are sharp, lack of selective gas adsorption on fresh mineral surfaces at low (room) T (observed from CO_2), and lack of high T gas reactions. In addition, all gases released in a particular crush are passed onto the column so that detection limits are not reduced by sampling smaller gas aliquots. The TCD and PID [detectors] have zero blanks at current detection limits, as determined by crushing heat treated (900°C/4 hrs.) Brazilian quartz (unheated Brazilian quartz gives a significant H_2O peak). The sample is degassed for ~15 hours at ~105°C, with the carrier gas flowing, prior to analysis. The lower crushing chamber is maintained at a higher gas P than the upper piston chamber so that any leakage is outwards. ~0.5 - 2.5 g of carefully selected, cleaned, sized (~1.5 - 5 mm) quartz, or ~2 - 5 g of more dense scheelite, are crushed in 2-4 steps to ~7000 psi. Gases are analyzed against standard mixtures; the linear behavior of the TCD response against peak area has been checked for CH_4, CO_2 and H_2O. The H_2O standard is the H_2O content of H_2O saturated air at measured T and P. The detection limit with the TCD and a HP 3392A integrator is estimated to be ~200 ppm molar in inclusions. The Nelson dual channel digital PC Integrator Package offers significant advantages since stored peaks can be accurately reintegrated off-line, and detection limits lowered by data expansion (e.g., ~30 ppm molar on TCD). The PID with a 11.7 eV lamp and digital peak processing gives significantly lower detection limits as low as ~1 ppm molar in inclusions (= ~3 picomoles) for gas species with ionization potentials ≤12.1 eV (e.g., H_2S, COS, NH_3, all hydrocarbons other than CH_4; not H_2O, N_2, CO_2, CO, SO_2, HCl, H_2 which show complex behavior).

A series of analytical procedures were tested and the elution times for various gases and columns are given. Some analytical data (qualitative) are presented for Tanco pegmatite, Manitoba, and Boss Mt. MoS_2 deposit, B.C. (Authors' abstract, abstracted by E.R.)

BREARLEY, Mark and **MONTANA, Art**, 1989, The effect of CO_2 on the viscosity of silicate liquids at high pressure: Geochim. Cosmochim. Acta, v. 53, p. 2609-2616. First author at Institute of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024-1567.

The effect of carbon dioxide on the viscosity of silicate liquids has been measured at high P and T using the falling-sphere method. Our measurements for viscosity of volatile-free $NaAlSi_3O_8$ liquid at 1400°C at 15-25 kbar are significantly lower than those determined previously by Kushiro (1978). Because of the low solubility of CO_2, and because CO_2 is probably a minor volatile constituent in silicic magmas, it will have a minor influence, compared to H_2O and F, on the modification of the physical properties of these magmas. Despite the relatively high solubility of CO_2 in basic magmas, it may be predicted that the viscosity of these magmas will not be greatly affected by the addition of CO_2. (From authors' abstract by E.R.)

BRENAN, J.M. and **WATSON, E.B.**, 1988, Fluids in the lithosphere, 2. Experimental constraints on CO_2 transport in dunite and quartzite at elevated P-T conditions with implications for mantle and crustal decarbonation processes: Earth Planet. Sci. Lett., v. 91, 141-158. Authors at Dept. Geology, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.

In a series of experiments at 0.5-1.3 GPa and 1050-1200°C we have monitored the transport, via crack propagation, of CO_2 into well-annealed olivine and quartz aggregates. The objectives were to determine (1) the extent and rate of fluid penetration; (2) the effect of varying both P-T conditions and microstructure; and (3) the fluid penetration pathways. Experiments on CO_2 penetration into dunite annealed in the absence of MgO indicate rapid and pervasive fluid transport on a grain-dimension scale, but a limited penetration distance (~1 mm). Additional experiments on dunite annealed in the presence of MgO (either dispersed or present at both ends), however, resulted in CO_2 penetration that was both pervasive on the scale of individual grains and almost always completely through the 5 mm long samples. The abundance of fine (10 μm) grains in the MgO-free dunite, in contrast to the much larger grain sizes of the samples annealed with MgO present, suggests the difference in fluid penetration behavior may arise because the strength variation in dunite scales with the grain size. Effects arising from changes in olivine point defect chemistry, however, are an additional possibility. The response of synthetic quartzite to CO_2 overpressure is distinct from that of dunite: Quartzite experiences rapid and complete penetration of CO_2, via a macroscopically visible system of transgranular fractures, over the range of P-T conditions investigated.

The small amount of porosity ($\leq$2-3%) present in most rock samples fabricated for this study lacks three-dimensional connectivity, thus precluding any enhanced fluid penetration via porous flow. Pores could possibly enhance fluid penetration as the result of a small reduction in resistance to fracture, but the probable abundance of strength-controlling flaws in natural rocks is likely to produce similar behavior.

The results of our experiments on olivine and olivine + MgO suggest that the transport of pressurized CO_2 in very olivine-rich mantle environments will be pervasive on the scale of individual grains and its extent may be dependent on rock microstructure and/or crystal chemical effects. Such pervasive fluid transport, perhaps associated with magma decarbonation, may have interesting implications for both magma transport and local LREE enrichment of adjacent mantle wall-rock. The ease with which quartzite is penetrated by CO_2 at the conditions of our experiments underscores the possible role of decarbonation reactions in crustal permeability-enhancement processes. (Authors' abstract)

BRENAN, J.M. and **WATSON, E.B.**, 1989a, Partitioning of REE's, Be, Ba, Cs, and Sr between clinopyroxene, olivine and carbonate melt at mantle conditions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A105.

BRENAN, J.M. and **WATSON, E.B.**, 1989b, High P-T solubility of olivine, orthopyroxene and Cr-diopside in H_2O-CO_2 fluids: Experimental techniques and preliminary results (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-94.

BRIDGWATER, David (ed.), 1989, Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, 416 pp.

Includes considerable discussion of the nature and movement of fluids as evidenced by fluid inclusions. Six of the most pertinent papers are individual listed here. (E.R.)

BRIL, H., 1989, Deposition conditions for some antimony (As) vein mineralization in the Hercynian basement: Data from fluid inclusions, W. Europe (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 17. Author at Lab. Géol., Univ. Limoges, 123 rue Albèrt Thomas, F-87060 Limoges Cedex, France.

Many berthierite-stibnite vein deposits hosted in metamorphic basement are not spatially associated with granitic intrusions. This style of mineralization is thought to be "epithermal" in origin, as indicated by the place of berthierite-stibnite vein deposits in "peribatholitic zonation." However results from recent FI studies of some Sb-As deposits in Hercynian basement (Brioude-Massiac, Haut-Allier, French Massif Central; Benevent, Lauriere, Limousin area, French Massif Central and Douro, North West Portugal) suggest a new interpretation of the thermal history of such deposits may be necessary.[1]

For all three areas, FI, studied in undeformed euhedral quartz crystals containing stibnite and/or berthierite have very similar characteristics, these are as follows:

(i) The presence of early low density carbonic FI with minor quantities of CH_4 and N_2 with Th >300°C.

(ii) Dilution with low salinity aqueous FI with Th between 250 and 350°C.

(iii) The presence of abundant, late aqueous FI at lower Th (250 to 150°C).

Other relevant information was obtained from geochemical and isotopic analysis. Moreover, similar data were obtained twelve years ago for a deposit in Finland.[2]

In conclusion, the genesis of this style of antimony (As) mineralization appears similar to that described for W deposits.[3] Concerning the relationship between vein-Sb and vein-Au deposits, it would be interesting to obtain further information concerning other Sb-As-Fe mineralization. Refs: 1. Brill, H. (1982) Ischermaks Min. Petr. Mitt., 30, 1-16; 2. Balitsky, V.S., et al. (1976) 25th Intern. Geol. Congress Abstracts; 3. Dubessy, J., et al. (1987) Bull Mineral., 110, 261-282. (Author's abstract)

BRIL, Hubert and BEAUFORT, Daniel, 1989, Hydrothermal alteration and fluid circulation related to W, Au, and Sb vein mineralizations, Haut Allier, Massif Central, France: Econ. Geol., v. 84, p. 2237-2251. First author at Laboratoire de Géologie, Univ. Limoges, 123 avenue Albert Thomas, F 87060 Limoges, France.

W,As,(Au) and As,Sb vein mineralizations in the Haut Allier (French Massif Central) are associated with ortho- and parametamorphic rocks containing biotite ± sillimanite, which have been locally intruded by small granitoid bodies. Hydrothermal alteration is well developed around these veins and has been studied here from a petrographic and a chemical point of view. The results are compared with those which were obtained by microthermometric study of fluid inclusions. In both mineralized types, three superimposed hydrothermal stages are distinguished, showing good agreement with the results obtained by other methods.

In the early stage, fluids enriched with $CO_2 \pm CH_4$ developed a quartz-2M1 muscovite assemblage (with 8% paragonitic substitution) at ~400°C. Minor chlorite appears, replacing biotite, near the transition of altered to fresh rocks. This early stage is predominant in veins with W,As,(Au) mineralization. In the intermediate stage, low-salinity aqueous fluids dilute the earlier fluids and control a new alteration with quartz-2M1 phengite ± carbonate assemblages at slightly lower T. This alteration stage is particularly important in the environment of veins with As,Sb mineralization. In the late stage, the last hydrothermal event occurs at a low T (<200°C) and forms a 1M illite-kaolinite ± quartz assemblage in small alteration veinlets.

Chemically, the different phyllosilicates that successively occur in W,As,(Au) and As,Sb veins are very similar. The differences between these mineralization types can be explained by the proximity of the granitoid bodies to W,As,(Au) veins and by a greater fluid/rock ratio involved in the alteration processes for As,Sb vein deposition. (Authors' abstract)

BRODSKY, N.S. and MUNSON, D.E., 1989, Crack healing studies in WIPP salt: Test methods and preliminary results (abst.): Eos, v. 70, p. 1323-1324.

BRILL, B.A., 1989, Trace-element contents and partitioning of elements in ore minerals for the CSA Cu-Pb-Zn deposit, Australia: Canadian Mineral., v. 27, p. 263-274. Author at Dept. Geology, Univ. Melbourne, Parkville, Victoria 3052, Australia.

The Se, Cd, Mn, Sn, Ag, Co and Ni contents of ore minerals from the CSA Cu-Pb-Zn deposit at Cobar, New South Wales, Australia, have been determined. The T of ore formation and the partitioning of Se, Mn and Cd between sphalerite and galena do not show a correlation; the trace elements in these mineral phases do not seem to indicate equilibrium. Partitioning of Fe and Zn between coexisting sphalerite and stannite give an ore-formation T of ~260°C. This value is lower than T interpreted from FI and compositions of chlorite, which average 350°C; this lowering is due to postdepositional, late metamorphic changes. FeS contents of sphalerite range from 14.7 to 11.8 mole % and indicate a P range from 4.8 to 7.9 kbar. The P are too high for metamorphic conditions at Cobar. The sphalerite likely reequilibrated at T below the metamorphic peak. The Co/Ni values of pyrite from Cobar ore are lower than those of most Cu-rich exhalative deposits, but are similar to those from remobilized vein deposits, and hence support the proposed metamorphic origin of the deposit. (Authors' abstract)

BROWN, K.L., 1989, Kinetics of gold precipitation from experimental hydrothermal sulfide solutions, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: Econ. Geol. Monograph 6, The Economic Geol. Publ. Co., p. 320-327. Author at Geothermal Research Centre, DSIR, Private Bag, Taupo, New Zealand.

The rate of change in the solubility of Au and, in one case, Ag has been measured as a function of changes in fO_2, fH_2, pH, and P. The experiments were carried out in a quartz-lined, stirred autoclave containing an aqueous H_2S-HS^- solution. Acidification of the solution causes a rapid decrease in Au solubility, an increase in fO_2 and depressurization cause a slower decrease, and an increase in fH_2 gives the slowest decrease in Au solubility. Increases in fO_2 as well as depressurization give initial increases in Au solubility. The interpretation is that loss of the HS^- ligand is the main kinetic control on Au concentration. The implications for ore deposition from geothermal fluid are that boiling, mixing with acid sulfate fluid, and mixing with oxygenated meteoric water could all be mechanisms for Au deposition. Acidification of Au and aqueous sulfide solutions results in rapid deposition of Ag. (Author's abstract)

BROWN, P.E., 1989a, FLINCOR: A microcomputer program for the reduction and investigation of fluid-inclusion data: Am. Mineral., v. 74, p. 1390-1393. Author at Dept. Geology and Geophys., Univ. Wisconsin, 1215 W. Dayton, Madison, WI 53706.

FLINCOR is designed to reduce laboratory data gathered on fluid inclusions and to calculate P-T isochores for geologically important fluids composed of H_2O, CO_2, CH_4, NaCl, CO, and N_2. Requirements for input data have been oriented toward the types of values derived from fluid-inclusion observations. Alternatively, fluid mixtures expressed in a variety of units (for instance, mole fraction), can serve as input data. The user can choose from among multiple published equations of state describing the fluid behavior and can readily compare the results obtained by using different equations. Calculated output can be either printed in tabular form or saved as an ASCII text file for exportation to other applications. FLINCOR is a Microsoft® Windows™ application. (Author's abstract)

BROWN, P.E., 1989b, FLINCOR: A fluid inclusion data reduction and exploration program (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 14. Author at Dept. Geol. and Geophys., Univ. Wisconsin, Madison, WI 53706.

FLINCOR is a user-friendly program written to run in the *Microsoft Windows* environment on an IBM (or compatible) computer. The program has been created for geochemists interested in (a) reducing FI laboratory measurements, (b) calculating isochores in P-T space from FI observations, (c) calculating isochores from hypothetical mixtures of fluids, and (d) comparing the results obtained by using various published equations of state to extrapolate fluid behavior and properties for geologically important fluids composed of H_2O, CO_2 and NaCl. Input data requirements have been slanted towards the kinds of observations made in a heating/freezing stage (e.g., freezing point depression, clathrate melting, Th L-V, total Th). However, in most cases, fluid mixtures expressed in a variety of units (for instance, mole fraction), can also serve as inputs. The user can choose from among published equations of state describing the fluid behavior and can readily compare the results obtained using different equations. Calculated results either can be printed in tabular form or saved as an ASCII text file for exportation to other applications.

As a teaching aid, FLINCOR provides an insight into the kinds of data required to describe a natural fluid system completely. It provides a friendly medium to compare one equation of state to another and to evaluate the ranges of geological conditions over which differences are significant. In addition it allows rapid determinations of the effects of uncertainties in the input parameters.

As a research tool, FLINCOR allows rapid data reduction of FI observations. On-line graphical displays will provide the researcher with immediate feedback on the implications of observations. Additional equations of state will be added to broaden the base of the program.

Enhancements to be added in the near future include simultaneous graphical output of the isochores, expansion of the program to consider other fluid species and combinations of species, the incorporation of additional equations of state, and the addition of an on-line help facility.

At present FLINCOR includes the following equations of state and approaches to data reduction: Bottinga and Richet (1981, Am. J. Sci., 615-660); Holloway (1981, MAC Short Course in Fluid Inclusions 6, 13-38); Kerrick and Jacobs (1981, Am. J. Sci., 281, 735-767); Bowers and Helgeson (1983, 1985, Computers Geosci., 11, 203-213); Zhang and Frantz (1987, Chem. Geol., 64, 335-350); and Brown and Lamb (1989, Geochim. Cosmochim. Acta, 53, in press). (Author's abstract)

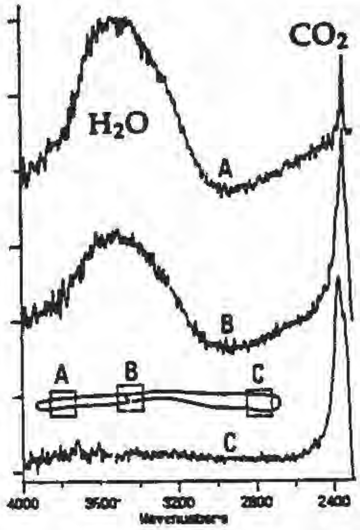
BROWN, P.E. and LAMB, W.M., 1989, P-V-T properties of fluids in the system $H_2O \pm CO_2 \pm$ NaCl: New graphical presentations and implications for fluid inclusion studies: Geochim. Cosmochim. Acta, v. 53, p. 1209-1221. First author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706, USA.

Understanding the role of fluids in geologic processes requires a knowledge of the P-V-T properties of fluids over a wide range of conditions. Comparisons of several published equations of state with available experimental data for fluids composed of H_2O and CO_2 lead to the conclusion that the hard-sphere modified Redlich-Kwong equation of state of Kerrick and Jacobs (1981) most accurately predicts the P-V-T properties in this binary system. To model the volumetric properties in the H_2O-CO_2-NaCl system a formulation is presented involving a linear (ideal) interpolation between a pure-CO_2 isochore predicted by the equation of state of Kerrick and Jacobs (1981) and an H_2O-NaCl isochore predicted by an empirical equation derived from the regression of available P-V-T data for the H_2O-NaCl system. This formulation is applicable over a wide range of T (>350°C) and P (2-10 kbars) and is especially suitable for high P and low-to-moderate T (fluid densities ≥ 1.0 cm^3). Determination of the appropriate isochore for an H_2O-CO_2-NaCl FI requires (1) the relative salinity (NaCl/H_2O + NaCl), (2) bulk density of the combined gas and liquid CO_2 phases and (3) volume percent estimate of the aqueous phase or the total Th. The commonly encountered problem of estimating the volume percents of phases in inclusions may be avoided in some applications, and several new P-X(CO_2) diagrams have been constructed and contoured with (a) the solvi in the mixed volatile system and (b) the measured density of the CO_2 phase. The effects of H_2O-CO_2 clathrates during microthermometric observations in the laboratory are evaluated and in most instances can be minimized or avoided.

Application of these results to FI studies have led to improved determinations of (1) P and T of fluid entrapment in a variety of geologic settings and (2) P and T of cooling and uplift following the peak metamorphism. Proper interpretation of FI data (From literature) for two granulite facies terranes suggests that the uplift P-T-t path is more nearly initially isobaric than has sometimes been presented. (Authors' abstract)

BROWN, P.E. and VRY, J.K., 1989, Micro-FTIR spectroscopy of H_2O-CO_2 fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A286. Authors at Dept. Geology and Geophysics, Univ. Wisconsin, Madison, WI 53706.

Analytical Fourier transform infrared spectroscopy (micro-FTIR) can be used to non-destructively analyze fluid inclusions for H_2O, CO_2, and other gases such as methane in minerals including quartz, fluorite and halite.



The Bio-Rad FTS-40 spectrometer is interfaced to a Bio-Rad UMA 300 microscope with a 100 micron square MCT detector and a 36X Cassegrain objective lens. A rectangular knife-edge aperture is used to select the area to be analyzed. The optimal 20 kHz scan speed allows 1024 scans at 3 wave number resolution in 300 seconds. On-line data reduction is provided by a computer workstation built around a 68020 microprocessor.

This hardware permits routine analyses of inclusions larger than 10x15 microns. Spectral information can also be obtained from much smaller parts of large inclusions (Fig. 1). The baseline corrected absorbance spectra in Figure 1 show the clear signals obtained from H_2O and CO_2 and demonstrate the spatial resolution of the system. The three spectra are serial 10 micron square sections (*A*, *B*, *C*) collected along the 75 microns long (3-5 microns wide) synthetic inclusion in quartz sketched on the figure. *A* corresponds to the H_2O end and shows the characteristic sharp single peak for the dissolved CO_2 (2345 cm^{-1}) and the large well-defined H_2O peak. *B* was collected straddling the meniscus between H_2O and CO_2, and *C* is the CO_2 end. The broad, multiple CO_2 peaks in *C* are apparently characteristic of dense CO_2 as are overtones which may appear near 3600 and 3700 cm^{-1}. Spectra of many potential host minerals, including quartz, are noticeably free of interfering peaks between 2300 and 4000 cm^{-1}. (Authors' abstract)

BROWNE, P.R.L., 1989, Contrasting alteration styles of andesitic and rhyolitic rocks in geothermal fields of the Taupo Volcanic Zone, New Zealand, *in* P.R.L. Browne and K. Nicholson (eds.), Proc. 11th New Zealand Geothermal Workshop: Geothermal Inst., Univ. Auckland, p. 111-116. Author at Geothermal Inst. and Geology Dept., Auckland Univ., Auckland, New Zealand.

Deep (1-2.25 km) drillholes at several geothermal fields in the Taupo Volcanic Zone, New Zealand, encountered thick sequences of Quaternary rhyolitic and andesitic rocks resting upon Mesozoic greywackes and argillites. The occurrence of andesites is uncommon in New Zealand geothermal fields but here allows comparison of their alteration with that of more silicic tuffs and lavas in a hot (250-320°C) environment in which circulate dilute alkaline chloride fluids of near-neutral pH. Fluid inclusion geothermometry measurements show that the observed hydrothermal minerals formed under the present field conditions.

The andesites are of medium K, calc-alkaline, orogenic type which, where fresh, contain calcic-plagioclase, augite, hypersthene, titanomagnetite and occasional hornblende. These phases typically alter to chlorite, calcite, epidote, clinozoisite, titanite, adularia, illite, pyrite and quartz, but veins mainly consist of different proportions of calcite, epidote, wairakite, adularia, chlorite and pyrite. The silicic volcanic rocks commonly alter to the same assemblages but the intensity of alteration of the two rock types differs considerably depending mainly upon how fluids move through them. Alteration intensity of the andesites changes sharply even over very short distances (order of cms) because thermal fluids move in them via joints; by contrast, the silicic volcanic rocks commonly have a much more pervasive and homogeneous alteration style consistent with thermal fluids penetrating them along grain boundaries and through interconnected pores. (Author's abstract)

BULANOVA, G.P., NOVGORODOV, P.G. and **PAVLOVA, L.A.**, 1988, The first occurrence of a melt inclusion in a diamond from the Mir pipe: Geokhimiya, no. 5, p. 756-765 (in Russian; translated in Geochem. Int'l., v. 25, no. 12, p. 129-137, 1989).

Translated in Fluid Inclusion Research, v. 21, p. 459-466.

BULEYKO, V.M. and **MAKOGON, Yu.F.**, 1989, Studies of thermodynamic properties of propane hydrate in the range of the phase transitions hydrate-ice and hydrate-water: Doklady Akad. Nauk SSSR, v. 309, no. 3, p. 663-666 (in Russian). Authors at All-Union Sci.-Research Inst. Natural Gases, Moscow, U.S.S.R.

Pertinent to cryometric studies of hydrocarbon-bearing fluid inclusions. (A.K.)

BURCH, T.E. and **COLE, D.R.**, 1989, Kinetics of stable isotope exchange in the system: Calcite-CO_2-H_2O at elevated temperatures and pressures (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A11.

BURKE, E.A.J., 1989, Quantitative laser Raman microspectrometry on fluid inclusions: An appraisal of five years of experience in Amsterdam (abst.) Symposium GEORAMAN 89, Toulouse, France, 17-19 May 1989, Abstracts (unpaginated). Also in Bull. Liason Soc. Franc. Mineral. Crist., v. 2, no. 1, p. 22 (1990). Author at Inst. Earth Sciences, Free Univ., P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.

Quantitative laser Raman microspectrometry (LRM) analysis of fluid inclusions in minerals and rocks has been carried out with the *Jobin-Yvon* MOLE at the end of the 1970's and in the early 1980's, e.g., Dhamelincourt et al. (1979), Bény et al. (1982), Guilhamou (1982) and Guilhamou et al. (1984). Reviews of the method and the results have been given by Dubessy (1985) and Touray et al. (1985).

In recent years several publications have raised questions and doubts about the accuracy and even the feasibility of quantitative LRM analysis (Wopenka & Pasteris, 1986; Seitz et al., 1987; Wopenka & Pasteris, 1987; Pasteris et al., 1988). The major problems discussed by these authors concern the uncertainty in the relative Raman scattering cross-sections (the σ's) of the components in high-density fluids, and instrumental difficulties particular to the *Jobin-Yvon* RAMANOR U-1000 system. The latter problem necessitates the users of this microspectrometer to derive individual instrument-specific "Raman quantification factors" to enable quantitative analyses.

The *Dilor* MICRODIL-28 microspectrometer (in its newest version called XY), however, has a construction which does not seem to result in instrument-specific errors in the quantitative analysis of fluid inclusions. Moreover, the multichannel detector of this system leads to a considerable lowering of detection limits and to much shorter measurement procedures (Burke & Lustenhouwer, 1987): the signal-to-noise ratio for comparable integration times is increased by at least one order of magnitude.

This high sensitivity of the Microdil-28, on the other hand, is the cause of a peculiar problem: the interference of atmospheric N_2 with the N_2 contained in fluid inclusions. This problem is evidently most disturbing with shallow inclusions of low density; it cannot be quantified because it depends on the polishing quality of the surface of the specimen. It can be solved, however, either by carrying out blank measurements next to the inclusions at the same depth of focus of the laser beam, or by directing a gas flow (e.g., of argon) between objective and specimen during the measurements.

More than 4500 spectra have been recorded on about 2000 inclusions with the Amsterdam Microdil-28 since its installation in January 1984. The results of these analyses have been incorporated in seven Ph.D. theses and in about 30 papers. Because of specific research subjects, almost all analysed fluid inclusions fall within the system CO_2-CH_4-N_2. Reviews have been published by Van den Kerkhof (1988a,b); see also Figure 1, in which gas compositions are given for inclusions from highly different metamorphic environments. It is obvious that most compositions fall on or near binary joints [joins] in the ternary system.

The compositions of the inclusions have all been calculated with the same σ's, regardless of density variations. The results are nevertheless considered to be relatively accurate because theoretical evaluations show that the effects of the internal field and the molecular interactions fall within the analytical error (Dubessy, 1985), and that the ratio of σ's remains unchanged over a wide range of P (Pasteris et al., 1988).

Independent data on the composition of fluid inclusions along the binary joints [joins] in the ternary CO_2-CH_4-N_2 system can be obtained from the interpretation of results of microthermometry measurements in combination with suitable equations of state. Examples of the internal consistency of Raman microspectrometry and microthermometry data are given by Darimont et al. (1988) in the system CO_2-N_2, and by Van den Kerkhof (1988a) in the system CO_2-CH_4; see also Figure 2. In our view, quantitative LRM analysis of high-density gaseous fluid inclusions does not present any particular problems. (Author's abstract; references omitted)

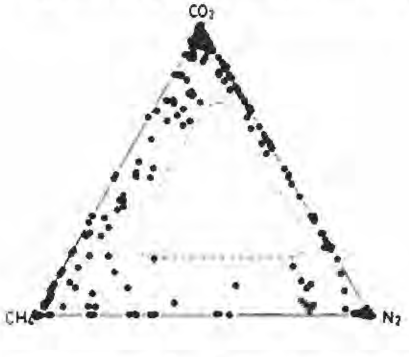


Figure 1. Gas compositions by Raman analysis of inclusions in the CO_2-CH_4-N_2 system of different metamorphic areas (Van den Kerkhof, 1988a,b).

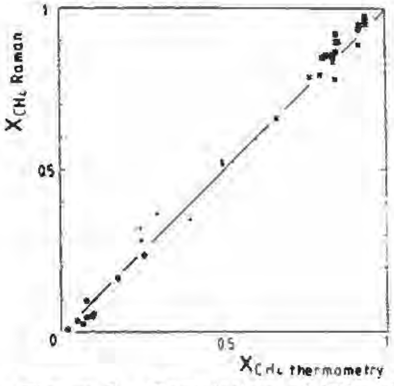


Figure 2. Correlation of CO_2-CH_4 compositions measured by Raman analysis and inferred from microthermometery data (Van den Kerkhof, 1988a).

BURKE, E.A.J., KERKHOF, A.M. van den and TOURET, J.L.R., 1989, Raman microprobe analysis of fluid inclusions in natural occurrences, from anchimetamorphic to eclogite-facies rocks (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A358. Authors at Inst. Earth Sciences, Free Univ., P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.

The application of laser Raman microspectrometry (LRM) to natural fluid inclusions aims at the acquisition of quantitative analysis of gaseous or fluid phases, and at the identification of enclosed solids (dms).

Several theoretical and practical considerations seem to prevent a straightforward use of LRM on fluid inclusions: preferred partitioning of components into different phases, shift in position and change in shape of Raman peaks with increasing internal P, uncertainties in the relative Raman scattering efficiencies of high-density fluids, effects of molecular interactions in fluid mixtures, instrumental difficulties, selective absorption by optical parts, interference from atmospheric N, spherical aberration of Raman scattering by the unique and usually irregular geometry of each single inclusion, etc. The identification of solids is difficult due to the lack of a catalogue with mineral spectra, to orientation effects, and to Raman inactive materials.

More than 2000 fluid inclusions have been studied with the system CO_2-CH_4-N_2 from widely divergent metamorphic environments. Gas compositions obtained with LRM (Microdil-28 multichannel detector system) correlate very well with phase transition T measured with microthermometry on the same inclusions and interpreted in theoretical PVT diagrams constructed with suitable equations of state.

Experimental results on high-density fluids and careful monitoring of instrumental LRM conditions indicate that most stated difficulties represent only marginal interferences within the overall limitations of LRM analysis of fluid inclusions. Results of LRM on dms can be correlated with electron-microscope/EDS data. (Authors' abstract)

BURLEY, S.D., MacQUAKER, J.H.S. and **ADAMS, A.E.**, editors, 1989, Theoretical Aspects and Practical Applications of Cathodoluminescence, Abstract Volume: Geology Dept., Manchester Univ., April 20-21, 1989.

Contains 22 papers on cathodoluminescence. (E.R.)

BURLEY, S.D., MULLIS, J. and **MATTER, A.**, 1989, Timing diagenesis in the Tartan Reservoir (UK North Sea): Constraints from combined cathodoluminescence microscopy and fluid inclusion studies: Marine and Petroleum Geol., v. 6, p. 98-120. First author at Geol. Inst., Univ. Bern, Baltzerstrasse 1, 3012 Bern, Switzerland.

FI occur in authigenic quartz, barite, ankerite and calcite cements that partially occlude inferred secondary porosity in Piper Fm sandstones of the Tartan field and adjacent Witch Ground Graben. Detailed petrography combined with hot cathodoluminescence studies enables a FI stratigraphy to be related to the authigenic minerals and individual cement zones within them. Microthermometric studies indicate that these inclusions formed at elevated T in the range 70-120°C. These T are interpreted to indicate hot migrating fluids invaded the on-structure sandstones at burial depths exceeding 1.5 km during the late Cretaceous-early Tertiary.

Between successive cement generations major fluctuations in salinity are recorded. There is a marked lowering of salinity between subsequent quartz generation. Barite and calcite cements, associated with metal sulphides, were precipitated from a low salinity brine. Ankerite cement at the present oil/water contact records precipitation from high salinity pore fluids. The salinity variations are thought to reflect large scale subsurface fluid migration. Sources of acidity for the generation of secondary porosity and sources of silica, sulphate and base metals for the pervasive late cements cannot all be found within the reservoir sequence. They therefore indicate mass transfer within an open system. The complex diagenetic assemblage is unlikely to have been precipitated from the evolution of a single pore fluid. Therefore, mixing of at least two subsurface fluids of very different chemistry and origin is inferred. Sulphate for barite and sulphide cements is thought to have been derived as a result of cross-formational flow from Zechstein anhydrite juxtaposed against the reservoir prior to oil migration.

Th of FI within cements along major fault planes are offset towards significantly higher T than those inclusions distanced from such faults. This, together with the distribution of porosity and cements on the crestal structures and adjacent to major faults, strongly suggests that the faults were the conduits for migrating hot fluids which mixed with the sulphate brine on the Taran structure. Seismic valving provides an elegant mechanism for transporting large volumes of hot fluids intermittently but repeatedly along the major bounding faults. The source of the hot fluid is inferred to be related to the dehydration and illitization of smectite reaction, maturation of organic matter and expulsion of pore waters in the adjacent Witch Ground Graben, all of which took place broadly coincident with the generation of secondary porosity and late on-structure cementation. (Authors' abstract)

BURLINSON, Kingsley, 1989, Decrepitation as an aid to microthermometry (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 15. Author at P.O. 37134, Winnellie 0821, N.T., Australia.

The method is capable of identifying CO_2-rich FI because they decrepitate at anomalously low T, as often noted during microthermometric studies. Suites of samples can therefore be quickly tested for the presence of CO_2-rich inclusions far more precisely than by manual searches of thin sections. Subsequent microscope work on samples elected on the basis of the decrepitation data can then provide the fine details. During a conventional microthermometric study of some 15 sections at the Enterprise Au mine, Northern Territory, Australia, the presence of CO_2-rich inclusions was not recognized and it was not until a decrepitation survey was later undertaken that the importance of CO_2-rich fluids in this deposit became apparent.

A study of auriferous quartz veins in West Australia was done using the clear (barren) vug filling quartz from the vein center, because the quartz at the vein margins (where the Au occurred) was milky and difficult to study microthermometrically. It was assumed that the quartz vein was homogeneous across its thickness and thus that the T result from the vein center would reflect the formation T of the mineralized vein walls. However, the decrepitation analyses of quartz from the vein center and margin were significantly different, suggesting that the assumption of homogeneous deposition is tenuous at best. Decrepitation data can quickly provide a preliminary test for such zonation effects to assist in the design and interpretation of an associated detailed microthermometric study.

Although the relationship between Td and Th is complex, when studying a suite of similar samples a useful relationship can sometimes be derived. By then using microthermometry as a control for a larger suite of decrepitation samples a more thorough study can be accomplished with little more effort. In one such study the decrepitation relationship having been derived, a large discrepancy between Th and T as inferred from decrepitation was observed on several samples. Upon reexamination of the sections of those samples it was found that some S inclusions had inadvertently been measured. Remeasurement of these samples gave T consistent with the decrepitation data and the use of both techniques in conjunction resulted in more accurate and consistent data.

Although it has been presumed that the decrepitation method would be prone to interference form S inclusions, in practice they do not interfere at all as no decrepitation is observed at the low T typical of S inclusions unless CO_2-rich fluids are present. This fortuitous curiosity is thought to be because the S inclusions, being small and decrepitating at low T, do not generate a large enough P pulse to be detectable in the current instrument (G. Hladky, personal communication).

The major problem in applying decrepitation to date is when the quartz has been recrystallized. In such samples only small inclusions remain, mostly along grain boundaries and these give no decrepitation response; nor are they usable ion microthermometric studies.

When used together and applied to a sensibly selected suite of samples the decrepitation and microthermometric methods can provide useful complementary information to improve the reliability and coverage of the data. Rather than being competing techniques, they are mutually advantageous. (Author's abstract)

See also Fluid Inclusion Research, v. 20, p. 57-58. (E.R.)

BURRUSS, R.C., 1989, Paleotemperatures from fluid inclusions: Advances in theory and technique, *in* N.D. Naeser and T.H. McCulloh, eds., Thermal History of Sedimentary Basins: Methods and Case Histories: Springer-Verlag, New York, p. 119-131.

FI in diagenetic minerals can be used to determine paleotemperatures. Three sets of observations are necessary to make accurate interpretations: (1) detailed petrography to establish the relative time of formation of the inclusions; (2) careful analysis of the burial and tectonic history of the host rocks to tie diagenesis to the geologic history of the basin; and, finally, (3) analysis of the phase behavior and chemical composition of individual inclusions to define the P-V-T properties of the trapped fluids.

Once these observations are complete, two major limitations remain in the interpretation of paleotemperature. First is the assumption that the inclusions have not altered in composition or volume since entrapment. Recently published work shows that inclusions can reequilibrate, but the extent to which that process affects most observations in sediments is unknown. Second, an independent measure of "paleopressure" during inclusion formation is necessary to distinguish whether the P was hydrostatic or approached lithostatic. Data from coexisting hydrocarbon and aqueous FI in core samples from the Mission Canyon Limestone (Mississippian), Williston basin, North Dakota, illustrate a method for independently determining both paleotemperature and paleopressure from a single set of FI measurements. The technique requires petrographic evidence for simultaneous trapping of two immiscible fluids. The P-V-T properties of such coexisting fluids require that the isochores for the two different fluids intersect at the T *and* P of entrapment of the inclusions. Calculation of the P-V-T properties of each fluid is based on detailed chemical analyses of both fluids. Recent results from new analytical techniques—especially capillary column gas chromatography to analyze hydrocarbon inclusions and laser Raman spectroscopy to analyze gases in aqueous inclusions—demonstrate that paleotemperature studies can be widely applicable in sedimentary environments. (Author's abstract)

CALLI, M., AURIOL, M., CAILLAT, C. and **TOLLON, F.**, 1989, Geochemistry and evaluation for ore deposits of Cros-Gallet-le Bourneix gold mine, Limousin, France (abst.): Terra abstracts, v. 1, p. 19-20.

The mine [shows] four successive mineralizing phases:

1. Auriferous deposits of mispickel I and II (pyrrhotite) pyrite, (300 to 350°C) in N 60°E mylonite (dextral shearing) in surrounding rocks (chlorite (Mg, Fe) and carbonates alteration: 280°C); Au in rocks is <6 g/t.

2. Local silicification and brecciation with milky white quartz cement.

3. Quartz breccia cataclasis and deposition of microcrystalline (or microsaccharoidal) quartz with mispickel III, native Au (15 to 45% Ag), (~450°C) by not very saline fluids (8 wt % eq. NaCl) with minor CO_2 and CH_4 content (P = 2 kbar); Au >15 g/t.

4. Hyaline quartz deposit in some tension fissures of quartz breccia with scarce native Au galena: their fluid inclusions indicate a mixing between CO_2-rich and lower CH_4 content vapor (T = 320°C, P = 0.6 kbar) and pre-existing solution (2 wt % eq. NaCl). Then, deposition of galena and sulfosalts (Pb, Sb, Ag, Cu) with electrum (Ag 50 wt %) in tension joints of these breccia cements. (From authors' abstract by E.R.)

CAMPBELL, A.C. and **EDMOND, J.M.**, 1989, Halide systematics of submarine hydrothermal vents: Nature, v. 342, p. 168-170. Authors at Dept. Earth, Atmospheric and Planetary Sciences, E34-254, Massachusetts Inst. Technology, Cambridge, MA 02139.

Chloride is the dominant anion in submarine hydrothermal fluids and plays a fundamental part in controlling their chemistry. The endmember Cl concentrations in virtually all submarine hot springs deviate from seawater (~541 mmol kg^{-1}) and range from 188 mmol kg^{-1} at the ASHES vents on Axial volcano to 1,090 mmol kg^{-1} at the Southern Juan de Fuca Ridge. A variety of mechanisms have been proposed to explain these Cl enrichments and depletions including: rock hydration and dehydration, phase separation, and the formation and dissolution of a retrograde soluble phase. Support for the latter hypothesis came from hydrothermal fluid/basalt experiments which showed large changes in dissolved Cl at specific reaction conditions and also from the presence of Cl-rich minerals phases in ultramafic rocks. We have carried out the first systematic study of Br and I in mid-ocean ridge hydrothermal vent fluids to constrain the models of halide diversity better by ascertaining their behaviour relative to Cl. The cohesiveness of the Br and Cl data and the similarity of Br/Cl to the seawater ratio suggests a single, non-fractionating process controls the salinity of sediment-starved mid-ocean ridge hydrothermal systems. The thermal decomposition of organic matter provides an additional source of Br and I in sediment-hosted systems. (Authors' abstract)

CAMPBELL, A.C., PALMER, M.R., GERMAN, C. and **EDMOND, J.M.**, 1989, The chemistry of hydrothermal fluids from the Escanaba Trough in comparison to sediment hosted and sediment starved vent systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-231.

CAMPBELL, Andrew and **PANTER, Kurt**, 1989, Fluid inclusions in quartz and wolframite from Cligga Head and St. Michaels Mt., Cornwall, England (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 16. Authors at Dept. Geosci., New Mexico Tech., Socorro, NM 87801.

The Cornwall mining district in SW England is well known for its W and Sn mineralization. We have studied samples from two areas, Cligga Head and St. Michaels Mount, adding to our on-going study of FI in wolframite. The goals of our work is [are] to further compare FI T and salinities, between wolframite and associated quartz and to provide new FI data for current studies of the deposits by several British research groups.

Both areas of mineralization are sheeted W veins. Mineralization consists of quartz, wolframite, cassiterite and various amounts of base metal sulfides. Associated wall rock alteration typically includes greisenization and argillization. In both areas textural evidence for contemporaneous deposition of wolframite and quartz is generally ambiguous. Previous studies state that the quartz and wolframite are intergrown but do not address the genetic relationship between them.

FI in wolframite were measured using an infrared microscope and those in quartz using visible light. All the inclusions observed in quartz and wolframite from Cligga Head were liquid-rich two-phase inclusions. P Th values for wolframite range from 255 to 418 and average 307°C. Salinity values range from 2.0 to 4.0 wt % NaCl. In S inclusions Th values range from 220 to 257°C and have salinities up to 11 wt % NaCl. In quartz P Th values range from 260 to 393 and average 297°C. Salinity ranges from 3.6 to 12.3 wt % NaCl. In S inclusions Th ranges from 235 to 250°C and salinities are about 4 wt % NaCl.

Inclusions in quartz and wolframite from St. Michaels Mt. are dominated by a liquid-rich, two-phase type. Small unidentified dms have occasionally been observed in quartz, but are absent in wolframite. Th values for P inclusions in wolframite range from 351 to 399°C with a mean of 369°C and for S inclusions from 255 to 330°C. Salinities average 4.2 wt % NaCl. P inclusions in quartz have Th values from 263 to 374 and average 311°C whereas S inclusions range from 250 to 300°C. Salinities average 7.3 wt % NaCl.

From these data, wolframite and quartz appear to have been deposited at Cligga Head at the same T. However, salinities of inclusions in quartz are slightly higher than those in wolframite. These minerals were deposited at slightly lower T than those determined for cassiterite by Jackson et al. (1977). Comparison of the previous data for cassiterite from St. Michaels Mt. with the new data from wolframite suggests that these two minerals were deposited at approximately the same T (370°C), which is ~55°C higher than the average depositional T of the associated quartz. This T discrepancy is not an effect of post trapping changes such as those caused by differing thermal expandabilities of ore and gangue; such changes would cause only minor differences in Th. It may be concluded that quartz precipitated at a different time than wolframite and cassiterite. Thus even though the intergrowth textures between quartz and wolframite are similar in both of these deposits, the two minerals appear to have been codeposited at Cligga Head but not at St. Michaels Mt. (Authors' abstract)

CAMPBELL, J.L., TEESDALE, W.J. and **MAXWELL, J.A.**, 1989, Micro-PIXE: A new analytical tool for mineralogists (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-68.

CANALS i SABATA, Angels, 1989, Physical-chemical characteristics of fluids from Rigros vein (Girona [Spain]): Fluid inclusion data and rare earth elements: Bóletin de la Sociedad Española de Mineralogía, v. 12, p. 283-293 (in Spanish, English abstract). Author at Dpto. Ciencias de la Tierra, Univ. Zaragoza, 50009 Zaragoza, Spain.

From fluid inclusions and rare earth elements data two kinds of fluids have been distinguished in the Rigros fluorine vein (Catalan Coastal Ranges). Fluid I, with T ~100°C and 21 eq. NaCl salinity, shows a rare earth elements spectrum characterized by a negative Eu anomaly and a nul or a light Ce negative anomaly. Fluid II, which has T between 160°C and 230°C, and a salinity ~17 eq. NaCl, shows a less specific spectrum with or without a positive Eu anomaly and a wide variety in Ce anomaly. Both fluids are polysaline. The fluid variation is interpreted as some variations in fluid source. (Author's abstract)

CANALS, Angels, CARDELLACH, Esteve and **AYORA, Carles**, 1989, The Eugenia mine (Pb-Zn-Ag) (Bellmunt Del Priorat, Tarragona): Fluid geochemistry and mechanisms of formation: Bóletin de la Sociedad Española de Mineralogía, v. 12-1, p. 80-81. First author at Dpto. Ciencias de la Tierra, Univ. Zaragoza, 50009 Zaragoza Spain.

According to fluid inclusion, stable isotope and mineral equilibria data, as well as to geological evidences, the deposition in veins with carbonatic gangue of the Bellmunt area (Eugenia mine) took place from brines at ~150°C, and at least 1 kb. A fO_2 of 10-49 ± 1 has been calculated from the CO_2/CH_4 ratio of fluid inclusions, from XFeS in sphalerite and the composition of chlorites. Under these conditions, changes in pH between 5 to 6.2 (stability of muscovite) may explain the observed isotopic variations in sulphur and carbon of sulphides and carbonates. Variations in pH as well as a small T decrease caused the precipitation of most minerals, and also explains the evolution of carbonate composition from ferroan dolomite and ankerite to calcite. The pH decreased to 5 (muscovite-kaolinite equilibrium) during the last stages of vein filling. The difficulty in explaining the transport of Pb and H_2S together in the same solution, at the indicated pH and T, suggests: (a) metals and sulphur were transported in different fluids (hypothesis not supported by the available isotopic and geochemical data), or (b) other unknown mechanisms of metal transport took place (a matter of debate among researchers on this type of low T deposit). (Authors' abstract)

CANALS-SABATE, A., TOURAY, J.-C. and **FABRE, J.**, 1989, Fluid inclusions in thernardite[sic], N. Mali: A microthermometric investigation (abst.): ECROFI, European Current Research on Fluid Inclusions, X

Symp., London, April '89, Abstracts, p. 18. First author at Dept. Ciencias de la Tierra, Univ. Zaragora, 50009, Spain.

Large thernardite[sic] crystals (10.30 cm long rosettes) have been sampled at New Agorgott, in the Taoudenni area (Northern Mali). They are still in equilibrium with a pressurized NaCl saturated brine capped by a halite layer. Clays located about 1 m above the thenardite occurrence have been dated at 6750 y BP (Fabre and Petit-Marie, 1988).

The crystals contain numerous, large sized, brine and solid inclusions (e.g., glauberite as determined by Raman microprobe). The microcryscopic data are compatible with additional $CaCl_2$ and/or $MgCl_2$ to the Na_2SO_4-NaCl-H_2O system (Te -31 to -35°C; unidentified salt or hydrate formed on freezing and melting in the 24.4 to 41.8°C range).

On the other hand, the Th of P FI scatter in the range 28 to 50°C. In order to understand the significance of the highest Th values, overheating experiments under 1 bar P have been performed at different heating rates until T_{Oh} = 170°C. The results are as follows:

(i) When T_{Oh} is > ~10°C, overheating is recorded and fossilized (identical Th after some hours, several days or 8 months storage at 5°C).

(ii) The lowest Th values (29°C) are probably near the lowest formation T of thenardite.

(iii) With T_{Oh} lower than about 60°C, a fair correlation is observed between Th and T_{Oh}.

Finally, taking into account recent natural overheating, FI data are compatible with a formation of thenardite from underground brines later than the beginning of aridification in the area (i.e., about 4000 y BP). (Authors' abstract)

CANDELA, P.A., 1989a, Calculation of magmatic fluid contributions to porphyry-type ore systems: Predicting fluid inclusion chemistries: Geochem. J., v. 23, p. 295-305. Author at Laboratory for Mineral Deposits Research, Dept. Geology, Univ. Maryland, College Park, MD 20902.

The composition of published FI analyses from a porphyry-type deposit are compared with the composition of a calculated magmatic aqueous phase. The calculations are performed by modeling the partitioning of Cl between an arc magma and an aqueous phase using a Nernstian law, and modeling the partitioning of the elements Na, K, H, Ca, Mg, Cu, Mn, and Ba into the chloride-bearing fluid according to experimentally determined exchange constants. The *instantaneous* concentration of the above elements in successive aliquots of magmatic aqueous phase evolved during second boiling can be calculated as a function of the vapor evolution progress variable. Further, an average concentration of an element in the magmatic aqueous phase (averaged over the course of vapor evolution progress) can also be calculated. The composition of the FI can be reproduced using both methods. Magmatic fluid compositions with 2000-3000 ppm Cu, 10 wt % Cl and K/Na ratios = 0.5 result from the calculations. Whereas K concentrations are slightly depressed, and Ca and Mg concentrations are elevated in the analyzed FI relative to the calculated fluids, the Na, Cl, Cu, Mn and Ba concentrations in fluids extracted from FI can be reproduced with these calculations. This study suggests that FI of the potassic zone of some porphyry-type deposits represent cooled magmatic fluids which have undergone some exchange with wall rocks but which contains magmatic concentrations of Cu, Mn and Ba at T <450°C. (Author's abstract)

CANDELA, P., 1989b, The physics of aqueous phase evolution in plutons (abst.): Eos, v. 70, p. 1416-1417.

CANDELA, P.A., BOUTON, L. and **PICCOLI, P.M.**, 1989, Chemistry of hydrothermal fluids from the Escanaba Trough in comparison and sediment starved vent systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-233.

CANDIOTTI DE LOS RIOS, H., NOBLE, D.C. and **McKEE, E.H.**, 1989, Geological setting, paragenesis, and zoning of epithermal silver veins of Arcata district, southern Peru (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-233-234. First author at Mauricio Hochschild y Cia. Ltda. S.A., Lima, Peru.

Arcata is the youngest known adularia-sericite-type deposit in the broad Miocene volcanic belt of southern Perú. The veins are hosted by intermediate lavas and breccias.

Fluid-inclusion studies by Prutek and Allen give Th for sphalerite between 230° and 270°C. Salinities are markedly higher for sphalerite and pyrargyrite (≥ 3 wt % NaCl eq.) than for quartz (≤2.5 wt %). Ore minerals and gangue apparently were deposited from compositionally distinct hydrothermal solutions, with the higher salinities of the metal-bearing solutions perhaps reflecting the input of a magmatic fluid component. (From authors' abstract by E.R.)

CANIL, Dante and **SCARFE, C.M.**, 1989a, Partial melting in peridotite + CO_2 systems at 5 to 9 GPa (abst.): Eos, v. 70, p. 483. Authors at Experimental Petrol. Lab., Dept. Geol., Univ. Alberta, Edmonton T6G 2E3, Canada.

Melting experiments were performed on two synthetic peridotites at P of 5 to 9 GPa. In both compositions, melting consumes the subsolidus carbonate (Mag) within about 30°C of the solidus. Melts generated along the solidus must therefore contain a significant carbonate component. The degree of partial melting in experiments above the solidus at 5 to 7 GPa was determined by point counting (1500 pts.) back-scattered electron image photographs of the run products. As much as 40% melt is generated within 40°C of the solidus. In contrast, melting experiments on peridotite + CO_2 at 3 GPa indicate that less than 10% melt occurs within 40°C of the solidus, and that carbonate is stable up to 100°C above the solidus. This contrasting melting behavior requires that the solidus and liquidus for peridotite + CO_2 converge (but do not necessarily meet) at P >5 GPa, and suggests that small excursions in T across the solidus of CO_2-bearing peridotite at depths >200 km in the upper mantle can produce SiO_2-undersaturated, CO_2-rich magmas. (From authors' abstract by E.R.)

CANIL, Dante and **SCARFE, C.M.**, 1989b, Origin of phlogopite in mantle xenoliths from Kostal Lake, Wells Gray Park, British Columbia: J. Petrol., v. 30, part 5, p. 1159-1179. Authors at Experimental Petrology Laboratory, Dept. Geology, Univ. Alberta, Edmonton T6G 2E3, Canada.

Phlogopite has been recognized for the first time in ultramafic xenoliths from the Canadian Cordillera. The phlogopite-bearing xenoliths are hosted in post-glacial basanitoid flows and ejecta of the Kostal Lake volcanic center, British Columbia. The xenolith assemblage consists of 60% cumulate-textured wehrlites, and 40% coarse-textured lherzolites, harzburgites, dunites, and olivine websterites.

The phlogopite occurs: (1) as sub-euhedral grains along grain boundaries in dunite and lherzolite xenoliths; or (2) along orthopyroxene lamellae exsolved from intercumulus clinopyroxene in the wehrlite xenoliths; or (3) as grains hosted in 10-100 μm diameter FI in clinopyroxene of all xenoliths. The phlogopites do not show any reaction relationships with other phases in any of the xenoliths studied. Phlogopites in a given xenolith have $Mg/Mg+Fe^{2+}$ similar to that of coexisting olivine, clinopyroxene, and orthopyroxene. The partitioning of Fe and Mg between phlogopite and coexisting olivine and clinopyroxene is similar to that observed in other phlogopite-bearing mantle xenoliths, and in high-P melting experiments on rocks with similar bulk compositions. This indicates that the phlogopites in xenoliths from Kostal Lake have equilibrated with these coexisting phases. The occurrence of phlogopites in FI containing Na, K, Cl, P, and S suggests that incompatible element-enriched hydrous fluids/melts fluxed this part of the upper mantle beneath eastern British Columbia. Metasomatism of the upper mantle beneath Kostal Lake probably occurred prior to Quaternary alkaline magmatism (7550-400 B.P.) and after the initial volcanism which formed the wehrlite cumulates (3-5 Ma). Metasomatism caused overall oxidation of the upper mantle beneath this area but was not responsible for the anomalously Fe-rich nature of some xenoliths from the Kostal Lake eruptive center. (Authors' abstract)

FI in cpx decrepitated during back-scattered electron imaging, leaving an evaporate residue with the composition listed, as determined by EDA. (E.R.)

CANIL, Dante and **SCARFE, C.M.**, 1989c, Solidus for peridotite + ' to 12 GPa and implications for the origin of melilitites and kimberlites (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-93.

CANN, J.R., RICHARDS, H.G. and **COWAN, J.G.,** 1989, Hydrothermal alteration patterns in ophiolites as a guide to plumbing systems below black smokers (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-234. Authors at Univ. Newcastle upon Tyne, Newcastle upon Tyne, U.K.

Massive sulfide deposits of ophiolites closely parallel, in geological setting, size range and types of sulfides, the deposits forming around black smoker hot springs on the ocean floor. Upflow zones can be traced up to a kilometer below the ancient ocean floor. Below these depths, and within the sheeted dyke complex, lie hydrothermal reaction zones characterized by the presence of epidosites (epidote-quartz rocks). These epidosite zones are elongate parallel to the dyke strike. The epidosite zones contain fluid inclusions of roughly seawater salinity with Th of ~350°C. The zones are strongly depleted in Cu, Zn and Mn relative to normal sheeted dykes, and show evidence of intense hydrothermal alteration. We interpret these zones as the regions in which cold seawater becomes heated, reacts with the rock and is transformed to hot hydrothermal solution, while the rock is altered and depleted in metals.

Immediately below the epidosite zones lie the gabbroic plutonics that represent the frozen axial magma chambers. The upper parts of these plutonics may show intense water-rock interaction, with high T fluid inclusions, but most of the plutonics show little sign of intensive alteration. The main source of heat for the hydrothermal circulation is thus probably the latent heat of crystallization of the magma in the magma chambers rather than the solid hot gabbroic rocks.

The inferred depth below the seafloor of the epidosite zones (1-2 km) is consistent with the depths derived from the geochemistry of modern hydrothermal solutions. We consider that we are seeing in ophiolites the deep levels of the hydrothermal plumbing that gives rise to black smokers, and have begun to make deductions about the compositions of the hydrothermal solutions involved in the alteration. Further integration of the two sources of evidence should yield new evidence about the processes taking place well below modern ocean floors. (From authors' abstract by E.R.)

CAO, Xiaoyun, RICHARDSON, S.M. and **RICHARDSON, C.K.,** 1989, Experimental studies of the hydrothermal transport and deposition of molybdenum (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A150-151.

CARIGNAN, J., GARIÉPY, C. and **HILLAIRE-MARCEL, C.,** 1989, ^{13}C, ^{18}O, ^{87}Sr/^{86}Sr, $^{208.207.206}$Pb/^{204}Pb isotopic constraints on the genesis of vein deposits from the St. Lawrence rift system (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-33. Authors at GEOTOP 7 SCT-UQAM, C.P. 8888, Succ. A. Montreal, Quebec, H3C-3P8, Canada.

Numerous Pb-Zn-F-Ba-bearing veins associated with the St. Lawrence rift system (Ottawa-Bonnechere and Saguenay) crosscut gneisses of the Grenville Province and Paleozoic limestones of the St. Lawrence Lowlands. Isotopic studies have been carried out on more than fifty of these post-Ordovician veins and their host rocks. The δ^{18}O and δ^{13}C of calcites from the veins show a positive correlation and range from +12 to +22‰ (SMOW) and from -12 to +3‰ (PDB), respectively. The stable isotope ratios are also correlated with the initial ^{87}Sr/^{86}Sr ratios (0.7129 to 0.7081) of the calcites. This reflects a mixing between distinct fluid and solid reservoirs. The T of formation of calcites (120°C), determined from FI studies, was used to calculate the isotopic composition of the mineralizing fluids and identify their origin: the fluids were part of a geothermal system involving meteoric water that has been enriched in ^{18}O by exchange with silicate phases. Carbon isotopic data indicate an input of "deep-seated" CO_2 from mantle degassing, the major faults of the rift acting as the plumbing system. No local isotopic exchange is observed between the veins and their host rocks. However the veins that crosscut marbles of the Grenville Supergroup have lower ^{87}Sr/^{86}Sr ratios and higher δ^{18}O and δ^{13}C values than those hosted in granulitic gneisses of the Charlevoix and Saguenay regions. We conclude that the mineralizing fluids have been globally modified when they intruded the metasedimentary pile. The initial Pb isotopic composition has been directly determined on galenas. The data show a wide variation (^{206}Pb/^{204}Pb = 18.0 to 19.7, ^{207}Pb/^{204}Pb = 15.50 to 15.72, ^{208}Pb/^{204}Pb = 37.9 to 41.0), and yield positive correlations in conventional Pb--Pb diagrams. This is interpreted as mixing between non-radiogenic Pb from the Grenvillian craton and very radiogenic Pb, potentially derived from late uraniferous granitic intrusions. (Authors' abstract)

CARLSON, E.H. and **LEACH,D.L.**, 1989, Fluid inclusion studies of epigenetic fluorite in the Findlay Arch region, Ohio and Indiana (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 17. First author at Dept. Geol., Kent State Univ., Kent, OH 44242.

Epigenetic fluorite, consisting of an early brown phase and a later yellow stage, is widespread in the middle Silurian to middle Devonian carbonate rocks of the Findlay Arch region. Brown fluorite was observed at 36 sites in an east-west elongated belt 190 km long and 130 km wide, extending from north-central Ohio into the northeastern corner of Indiana; the yellow phase occurs over a larger region. Associated minerals include: barite, calcite, celestite, dolomite, galena, marcasite, pyrite, sphalerite, strontianite and sulfur.

Fluorite was selected for inclusion studies because its well-documented paragenetic position and broad distribution in the region could be expected to yield important data about the T and compositions of the included brines and possible regional variability. Values of Th and Tm were obtained for 32 P inclusions in brown fluorite from seven sites and for 44 S inclusions in yellow fluorite from seven sites; four of the sites provided data for both phases.

P inclusions generally appear as negative crystals and exhibit low Th and salinities, with values of Th and Tm extending from 45° to 94°C and -13.4° to -30.4°C, respectively. Th of different inclusions in a crystal characteristically yield a range of several tens of degrees while Tm ice of the same inclusions display a range of a few degrees; some of the variability in Th may be due to leakage of the included fluids rather than stretching. These data exhibit two significant regional patterns: (1) salinities that decrease in a westward direction, and (2) salinities that decrease concordantly with decreasing Th. Taken together these trends suggest that the included Ca-rich brines originated in the Appalachian Basin and were diluted with cooler meteoric waters as they migrated westward across the arch. The apparent restriction of dxl salts to inclusions at the eastern edge of the area would appear to support a source in the Appalachian Basin.

S inclusions provided Th in the range 79° to 123°C and high salinities, with values of Tm extending from -17.4° to -31.1°C. The Th of the S inclusions, which typically exhibit a range of about ten degrees at a site, document a later heating event of regional scale. Although the salinities decrease westward across the arch, no correlation is apparent between the salinities and Th. (Author's abstract)

CARMICHAEL, I.S.E, 1989, Oxygen fugacities and redox states of magmas (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-240.

CARPENTER, A.B., 1989, Occurrence of lead- and zinc-rich brine in the Rotliegendes Formation, The Netherlands (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A315.

CARROLL, J.J. and **MATHER, A.E.**, 1989, The solubility of hydrogen sulphide in water from 0 to 90°C and pressures to 1 MPa: Geochim. Cosmochim. Acta, v. 53, p. 1163-1170.

CARROLL, M.R., 1989, The effect of He on the solubility of Ar in silicate solids and liquids (abst.): Eos, v. 70, p. 1402.

CASAS, Enrique, LOWENSTEIN, T.K., SPENCER, R.J. and **ZHANG, Pengxi**, 1989, Mechanism of potash salt mineralization, Qaidam Basin, western China: Evidence from surface brines, pore fluids, and fluid inclusions in halite (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A315. First author at Dept. Geological Sciences, SUNY, Binghamton, NY 13901.

The nonmarine Qaidam Basin, western China, contains modern potash deposits (carnallite-$KCl.MgCl_2.6H_2O$) at the surface and as early diagenetic void-filling cements. Carnallite-saturated surface brines at Dabusun Lake form from mixtures of two types of inflow waters (Na-HCO_3-rich meteoric river water and $CaCl_2$-rich spring inflow), evaporative concentration, and recycling of salts (dissolution of carnallite).

A mechanism of precipitation of carnallite cement from groundwater brines is based on pore fluid chemistry, measured T profiles, and the melting behavior of fluid inclusions in halite from two 50 m cores. Carnallite cements occur to depths of 13 m, and brines at or near carnallite saturation occur to depths of 18 m. Brines trapped in fluid inclusions in halite are well below carnallite saturation except in the youngest halites near the surface (0.5 m). This indicates that potash salt formation may be a recent phenomena. We postulate downward, density driven migration and cooling of carnallite-saturated brines as a major mechanism for the precipitation of potash mineral cements. T profiles from the northern margin of Dabusun Lake (August 1988) support this interpretation. Halite + carnallite-saturated surface brines were up to 47.5°C (air T of 30°C). Groundwater brines at 0.6 m were 21°C and those from 9 m were 11°C. Because of the strong T control on carnallite solubility, surface brines, when cooled, become saturated with respect to carnallite. (Authors' abstract)

CATHELINEAU, M., BASTOUL, A.M., LESPINASSE, M., BERNARD, C. and **LEROY, J.**, 1989, Fluid migration during contact metamorphism: The use of oriented fluid inclusion trails for a time/space reconstruction (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 19-20. First author at CREGU, BP 23, 54500, Vandoeuvre-lès-Nancy, France.

Microthermometric characteristics of metamorphic to hydrothermal fluids and microfaulting were studied in a contact zone between metamorphic series and peraluminous granites, located in the southern part of the Mont Lozere pluton (Massif Central, France).

Four major stages of fluid production or migration have been recognized in this area:

(i) N_2CH_4 ($\pm CO_2$) rich fluids related to the metamorphism of the C-bearing shales, occurring as FI along quartz grain boundaries.

(ii) CO_2-CH_4-H_2O vapors or liquid, with Th of 400 ± 20°C, and 250 ± 50°C respectively, related to the first hydrothermal stage produced by the late peraluminous intrusions.

(iii) Aqueous fluids with low salinities and Th in the range 150-300°C.

(iv) Low T aqueous fluids.

It is shown that the percolation of hydrothermal fluids occurs through a dense set of microfissures on all scales. The different stages of fluid percolation have been investigated by relating fracturing, deformational events related to the observed fracturing and the nature of hydrothermal fluid by studying the trails of FI. Analysis of their relationships with plastic deformation structures shows that their propagation is independent of intracrystalline anisotropies. Combined studies of their spatial orientation and microthermetric characteristics show that:

(i) According to the orientation, several generations of fluids can be distinguished in a sample as a function of their physico-chemical characteristics (P, V, T, X). They correspond to different stages of the hydrothermal activity and to different directions of microcrack opening.

(ii) In isotropic media (granite), FI trails are mode I cracks which can be used as excellent markers of palaeostress fields. However, in anisotropic media (quartz lenses in micaschists) the migration directions of the fluids are mostly dependent on the local direction of microfracturing.

The study of the contact zone between granites and a metamorphic series subjected to local abnormal heat flows shows that fluid characteristics are significantly different in the two environments. Migration of carbonic fluids from the micaschists towards the granites occurred but was relatively limited, whilst aqueous fluids mixed in variable amounts of carbonic fluids in the metamorphic zone. (Authors' abstract)

CATHELINEAU, M., DUBESSY, J., BASTOUL, A.M. and **BOIRON, M.C.**, 1989, Fluid-mineral equilibria in hydrothermal gold veins (abst.): Terra abstracts, v. 1, p. 25-26.

Fluids together with alteration and ore mineral assemblages were studied in representative hydrothermal gold veins from the western part of the Variscan belt in France (Au mines of La Bellière, Salsigne, Villeranges, Le Châtelet, and Limousin occurrences), in Canada (British Columbia) and in Morocco (Tichka). Systematic studies of fluid inclusions in the gangue minerals (quartz, calcite, ankerite) of Au ores show that two different types of Au veins can be distinguished: (1) those deposited at low T and P (150-250°C, <500 bars) from almost purely aqueous fluids (H_2O-NaCl) and characterized by Au-rich arsenopyrite and pyrite (Châtelet, Villeranges), and (2) those showing a multistage evolution in fluid composition and ore deposition in quartz veins exhibiting complex fracturing, shearing and microcrack healing (shear zone of Brittany and Limousin, Canada). Ores (Au + sulphides) and inclusions of ore fluids occur mainly within small microcracks where the early milky quartz is recrystallized. Two types of conditions have been recognized: (a) relatively high T (250-400°C) and P (>1 kbar) with CO_2-CH_4-H_2S ($\pm H_2O$-NaCl) rich fluids related to the early sulphide deposition; (b) lower T (150-250°C) and P with aqueous fluids related to the late native Au-sulphide assemblage, which constitutes the economic ores in some deposits.

Consideration of chemical equilibria in the C-O-H-S system using microthermometric and Raman spectrometry data on fluids together with the data obtained from mineralogical studies shows that during Au deposition, fO_2 was rather low, below H-M at Villeranges, around that fixed by the Ni-NiO oxygen buffer in Canada and at La Bellière, and lower than Ni-NiO in Morocco. fS_2 was relatively high (pyrrhotite instability) and pH rather low as shown by the complete alteration of the host rocks into a quartz-illite assemblage. The different conditions illustrate the evolution of fluid circulation from metamorphic conditions, in some cases linked to magma intrusions towards late hydrothermal system of the geothermal type. (Authors' abstract)

CATHELINEAU, M., DUBESSY, J., MARIGNAC, C., VALORI, A., GIANELLI, G. and PUXEDDU, M., 1989, Pressure-temperature-fluid composition changes from magmatic to present day stages in the Larderello geothermal field (Italy): *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 137-140. First author at CREGU, Vandoeuvre, France.

See Fluid Inclusion Research, v. 21, p. 65-67. (E.R.)

CATHELINEAU, M., IZQUIERDO, G. and NIEVA, D., 1989, Thermobarometry of hydrothermal alteration in the Los Azufres geothermal system (Michoacan, Mexico): Significance of fluid-inclusion data, *in* K. Grönvold, guest-ed., Water-Rock Interaction: Chem. Geol., v. 76, p. 229-238. First author at CREGU et GS-CNRS-CREGU, F-54501 Vandoeuvre-lès-Nancy, Cédex, France.

FI were analysed systematically in samples from different wells and depths of the Los Azufres (Mexico) active hydrothermal system. Fluids were studied either in authigenic minerals (P inclusions) in quartz, calcite or anhydrite, or in magmatic minerals (S inclusions in microcracks). The fluids are aqueous and have low salinity, ~1 eq. wt % NaCl. They were trapped in P-T conditions very close to that fixed by the L-V equilibrium curve. Fluid P is lower than the calculated hydrostatic one assuming a liquid-dominated system, because of the existence of a two-phase vapor-dominated zone at a depth between 500 and 1500 m.

T was estimated also by a good number of techniques. Present-day distribution of T is given by direct measurements in the wells by Kuster® equipment. Downhole T may be estimated using different dissolved species geothermometers and the chemical composition of the produced fluids. The present-day measurements above the downhole give in general lower estimates than those obtained by other means. However, agreement between downhole T, chemical geothermometer estimates and FI data is relatively good. (Authors' abstract)

CATHELINEAU, M. and LESPINASSE, M., 1989, Quartz dissolution in microfractured crystalline rocks: Physical and chemical conditions, thermodynamical modelling of the process, and fluid migration reconstruction: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 133-136. Authors at CREGU and G.S. CNRS-CREGU, Vandoeuvre les Nancy, France.

The hydrothermal leaching of quartz is one of the commonly found types of subsolidus alteration in crystalline rocks. It is frequently associated with Na and/or K metasomatism, which promotes important alterations in the primary mineralogy of rocks. The physical and chemical conditions of the process have been estimated from systematic mineralogical and fluid inclusion studies: fluids belong to the H_2O-NaCl system, have low salinities, and are trapped as fluid inclusions of highly variable densities, at ~350 ± 50°C. The initial undersaturation with respect to quartz is provoked by the mixing of fluids having similar compositions but different densities and T. At the mixing T, the quartz solubility in a fluid of intermediate density (fluid density after mixing) is higher than the quartz solubilities in the two initial fluids, thus yielding quartz dissolution. Geometry of the fluid migration has been determined by combining data obtained on microstructural markers (microcracks and fluid inclusions trails related to the quartz dissolution process) and from the stress field reconstruction. A geochemical modelling was made using the chemical and physical data obtained from the mineralogical and fluid inclusion studies. (Authors' abstract)

CERLING, T.E., 1989, Does the gas content of amber reveal the composition of palaeoatmospheres?: Nature, v. 339, p. 695-696. Author at Dept. Geology and Geophysics, Univ. Utah, Salt Lake City, UT 84112.

What does the gas content of amber indicate? It has been suggested that bubbles in amber preserve the composition of the atmosphere at the time the amber was exuded from trees, while others suggest that the gas content is controlled by solubility relationships, diffusion or chemical reactions involving O consumption. Here I describe a combined study of N, Ar and O in amber which makes it possible to distinguish bubble gas from matrix gas in amber by considering N_2/Ar and O_2/Ar ratios of the first gas released during the crushing of individual amber samples. Crushing experiments do not indicate high O levels in Cretaceous amber as have been recently reported. Neither Baltic nor Cretaceous amber has even the amount of O expected for equilibration with the modern atmosphere. Successive crushings of individual amber pieces show that the first crush has the highest O content and that both bubble and matrix O is consumed as crushing continues. These results suggest that the O content of amber does not have a bearing on the composition of palaeoatmosphere. (Authors' abstract)

CHACKO, Thomas, MAYEDA, T.K., CLAYTON, R.N. and **GOLDSMITH, J.R.,** 1989, An experimental determination of $^{18}O/^{16}O$ and $^{13}C/^{12}C$ fractionations between CO_2 and calcite at 10 kbar (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A11.

CHAI, Sheli, 1989, Geology and geochemistry of Yuerya gold deposit: J. Changchun Univ. Earth Sci., v. 19, no. 3, p. 271-278, abstr. on p. 298 (in Chinese, English abstract).

The Yuerya Au deposit is located in Kuanchen country, Hebei province. The main country rock is the Yuerya granite. According to the spatial distributions and forms of ore bodies, it could be divided into three ore belts, the south, middle, and north. The major ore mineral is pyrite, and pyrrhotite, chalcopyrite, sphalerite, galena, and molybdenite, etc. are subordinate. The mineralization type is referred to Au-bearing sulfide-quartz vein. Based on the study of geochemistry of the Au deposit, the author holds that it is a typical magmatic-hydrothermal ore, possibly derived from the deep crust. The Co/Ni ratio of pyrite is 1.58; La/Yb ratio of quartz, 2.95; total sulfur isotope composition of hydrothermal solution, +2.6‰; δO_2, +7.03‰; δD_1, -88.4‰; $\delta^{13}C$, -4.18‰; ore-forming T, 305~343°C; and pH, 6.2~6.8 Cl^- is $>F^-$, and $Na^+ > K^+$ in quartz inclusions, indicating that Au was probably transported as $Na[AuCl_2]$, $Na[AuCl_4]$, Na[AuS] in the hydrothermal solution. (Author's abstract)

CHAN, L-H. and **EDMOND, J.M.,** 1989, Lithium isotope characteristics of submarine hydrothermal fluids (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-258.

CHARLES, R.W., GOFF, F., JANECKY, D., JANIK, C.J. and **HULEN, J.B.,** 1989, State of equilibrium and ore mineralization in Core Hole VC-2a, Sulfur Springs, Valles Caldera, New Mexico (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-263-264. First author at Los Alamos Nat'l Laboratory, Los Alamos, NM.

The core hole penetrates the most intensely altered and thermally active portion of the Valles Caldera complex. It was anticipated that Creede-type mineralization might be discovered in VC-2a. Instead of Creede-type mineralization, alteration in VC-2a includes a sub-ore grade epithermal molybdenum deposit—a unique occurrence in an active geothermal system. Molybdenite mineralization [is] associated with quartz, illite, and pyrite. Other phases found less commonly in the molybdenite zone are fluorite, gypsum, sphalerite, and rhodochrosite. Veins show a complex sequence of mineralization evolving with time: molybdenite-pyrite-illite-quartz; quartz; quartz-illite; quartz- fluorite; rhodochrosite-sphalerite. Fluid inclusion T show all assemblages crystallized at about 200°C. (From authors' abstract by E.R.)

CHAROY, B. and **POLLARD, P.J.**, 1989, Albite-rich, silica-depleted metasomatic rocks at Emuford, northeast Queensland: Mineralogical, geochemical, and fluid inclusion constraints on hydrothermal evolution and tin mineralization: Econ. Geol., v. 84, p. 1850-1874. First author at Equipe Physicochimie des Fluides, Centre de Recherches Petrographiques et Geochimiques, B.P. 20, 54501 Vandoeuvre-les-Nancy, France.

Late Paleozoic fluorine-rich granites and their host metasediments in the Emuford district of the Herberton tin field contain small zones of intense albitization that host cassiterite mineralization. Sodium metasomatism was accompanied by hydrothermal leaching of granite quartz to form vuggy albite rocks (episyenites). Vugs created by quartz dissolution were filled in by hydrothermal minerals, including albite, K feldspar, and/or muscovite and cassiterite; late phases are dominated by quartz and fluorite. Swarms of parallel veinlets crosscut the albitized zones. These veinlets were formed by repeated fracturing in response to local fluid overpressures. They contain infill mineralogy similar to the vugs and probably formed at least partly contemporaneously with vug infill.

Due to the overprinting at various scales of alteration, vug infill, and vein formation stages, chemical changes associated with episyenite formation are only qualitatively constrained. However, the mineralogical and textural features of the alteration zones suggest that most major and trace elements had substantial mobility during their formation. Major chemical changes associated with episyenite formation include leaching of SiO_2, K_2O, Rb and Ba, with introduction of Na_2O and minor Sr. During vug- and vein-filling stages there was an introduction of SiO_2, Al_2O_3, Na_2O, K_2O, CaO, F, and Sn. The erratic behavior of REE is probably related to the growth of fluorite and minor accessory phases (zircon, monazite, xenotime), with preferential enrichment of heavy REE in rocks with the highest fluorine concentrations.

Fluid inclusion study indicates that vug- and vein-filling stages of the hydrothermal evolution involved two types of fluids. A high-salinity fluid (30-50 eq. wt % NaCl) of probable magmatic origin and $Th \leq 428°C$ was associated with vug filling in the granite-hosted deposits. A lower salinity fluid (5-15 eq. wt % NaCl), containing variable amounts of CO_2 and having Th between 160° and 420°C, was associated with veinlet formation in the granite-hosted deposits and with vein and cavity filling in the metasediment-hosted deposit. This lower salinity fluid may represent a condensed vapor phase derived from boiling of the magmatic fluid or may be a mixture of magmatic and meteoric components.

The close association of albitization and quartz dissolution suggests a genetic link between the two processes. It is proposed that exchange of Na for K in the fluorine-rich hydrothermal fluids caused a substantial increase in quartz solubility and led to quartz dissolution in the albitized rocks. (Authors' abstract)

CHATTOPADHYAY, P.B., 1989, Fluid inclusion and mineragraphic studies of quartz veins associated with gold/tin/tungsten mineralisation in West Bengal, Andhra Pradesh and Madhya Pradesh with special reference to their genesis (abst), *in* D.P. Dhoundial, ed., Extended abstracts of progress reports; field season 1987-88: Geol. Surv. India, Records Geol. Surv. India, v. 122, (2), p. 50.

CHEN, Anfu, 1989a, Application of fluid inclusion analysis in oil and gas exploration (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-271. Author at Beijing Uranium Geological Research Inst., Beijing, P.R.C.

Application of fluid inclusions in oil and gas exploration is as follows: (1) to determine T and P of a basin during formation and thermal history; (2) the physical and chemical conditions when organisms changed into hydrocarbons; (3) chemical and isotopic compositions; (4) to combine information of petroleum fluid inclusions with abnormalities of physical and chemical exploration to determine rich-oil layer, reservoir, and nonreservoir location.

Four types of fluid inclusion were discovered in organic limestone of Permian and Tertiary ages in the Redwater oil of fluid inclusion in gas hydrocarbon inclusion [sic]. The gas type of inclusion represents about 70% of the total inclusions. The compositions of the gas phase are 70% CH_4, 20% C_3-C_4, and 5% CO_2. The information from fluid inclusion analysis of yields as well as depth: depth of 2453 M, Th 160-240°C, P 580 x 10^5 pa, 3508 M, Th 190-220°C, P 930 x 10^5 pa. 1-4 wt % NaCl, $\delta^{18}O$ + 2.2 % (SMOW), δD-54.8% (SMOW), and $\delta^{13}C$ - 47% (PDB) [sic]. The information obtained from these fluid inclusions shows that organisms changed into hydrocarbon at 80-200°C, 600-1000 x 10^5 pa. The rich-hydrocarbon layer is organic limestone of Permian and Tertiary periods of which gas hydrocarbons are more important.

In the middle oil fields of HeNan Province [sic], the source rock is sandstone. There are many rich-hydrocarbon fluid inclusions in the recrystallized quartz in the sandstone. The information of fluid inclusions show that Th 80-120°C, salinity 8-10 wt % NaCl, and the physical-chemical conditions are suitable for the conversion of organisms into hydrocarbons.

The fluid inclusion study of natural gas, in eastern Sichuan, shows that the formation conditions of gas were as follows: Th 150-250°C; 10-20 wt % NaCl, C_1/C_4 3:2; C-55-60% (PDB). Depth of formation is lower than 3000 M. These data suggest that natural gas was formed by organisms and are super-ripened dry gas. (Authors' abstract) [sic; see p. 1]

CHEN, Anfu, 1989b, Three haloes exploration method of fluid inclusions: New uranium and gold deposit exploration method (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-276. Author at Beijing Uranium Geological Research Inst., Beijing, P.R.C.

When hydrothermal solutions transport U and Au through surrounding wall rocks, they formed a great deal of fluid inclusions. By measuring these fluid inclusions, we can obtain information about anomalous areas of T, chemical composition, and counts of fluid inclusions in the promising area. They can be called hot halo, gas halo, and vapor halo. Three halos of fluid inclusions always appear at the top of a U and Au deposit.

Samples are taken from an exploration area in a 20 x 40 m or 40 x 80 m net. Then we measured Td, counts of fluid inclusion decrepitation, and releasing gas compositions. The anomaly map can be made by each group of information, using anomaly maps combined with geologic characteristics to choose the important anomalous area.

We have found several blind U deposits in granite in GuangXi Province [sic]. Out of 15 drill holes, 12 of the holes discovered ore bodies at 200-290 m deep, and content of U is 0.3-0.5%. Three Au deposits have been found in northeastern China, also using the three haloes exploration method. Ore bodies are 150-300 m deep, and Au content is 5-15 g/T.

A new type of three halo exploration instrument has been made by our institute. It is SJ-950 fluid inclusion decrepitation analyzer.

At present, the three halo exploration method of fluid inclusion has become a new exploration method. By our study results, the rate of discovery of blind ore bodies is about 70%, and exploration depth is about 200 m. (Authors' abstract) [sic; see p. 1]

CHEN, J.C. and **OWEN, R.M.**, 1989, The hydrothermal component in ferromanganese nodules from the southeast Pacific Ocean: Geochim. Cosmochim. Acta, v. 53, p. 1299-1305. First author at EMCON Assoc., Glendale, CA.

The first quantitative determination of a significant hydrothermal end-member in ferromanganese nodules. Nodules apparently acquire a hydrothermal component through the accretion of colloidal-sized hydrothermal precipitates which are widely dispersed from their origin at vents along the East Pacific Rise (EPR). Nodules recovered from beneath the "shadow" of the present-day hydrothermal plumes emanating from the EPR contain significantly higher amounts of hydrothermal material relative to nodules from other areas. (From authors' abstract by E.R.)

CHEN, Zhensheng and **ZHANG, Ligang,** 1989, A typical meteoric-hydrothermal deposit: Stable isotope evidence for the genesis of Bainaimiao gold deposit in Inner Mongol[ia]: J. Guilin College of Geol., v. 9, no. 1, p. 61-68 (in Chinese, English abstract). Authors at Yichang Inst. Geol. and Mineral Resources, Ministry of Geology and Mineral Resources, Hubei, P.R.C.

Through systematic O isotope sampling and analysis of lodes and their wall rocks in Bainaimiao Au mining area in Inner Mongolia and determination of H isotope compositions of I water in quartz veins, it is indicated that the O isotope compositions of vein quartz range from +4.37 to -1.19‰, and the H isotopic composition range of vein quartz I is from -108.9 to -133.8‰. Combining the other information, the authors suggest that meteoric water is the dominant component of the ore-forming solution in this region, while strong structure crushing, driving of heat power from granitoid intrusive bodies and the regional Au source bed enable this fluid to leach mineral materials and deposit them at favourable structural places. (Authors' abstract)

CHEN, Ziying, XIA, Weihua and FENG, Zhiwen, 1989, Fluid inclusion study on main types of gold deposits in China (abst.): Progress in Geosciences in China (1985-1988)—Papers to 28th IGC, v. 1, p. 41-42. Authors at China University of Geosciences, Wuhan, China.

The results of FI study on main types of Au deposits in China are presented. Some models proposed for the genesis of the ores are based on both the FI data and other geological conditions.

The Zhao Yuan-Ye Xian Au belt [which] is one of the most important Au mineralization areas in China, occurs in a fault zone near the contact belt of metamorphic volcano-sedimentary series of Proterozoic Jiaodong Group and remelted granite. The data of FI of the mineralized vein from two types of Au mineralization (auriferous quartz type, tectonic alteration type) show that both H_2O and H_2O-CO_2 fluids were present during the mineralization event. Thermometry and barometry show that the ores were formed at 235-240°C and 400 bar which correspond to a depth of 1500 m.

Bulk I analysis and microthermometric analysis of FI in quartz veins have been made to characterize the composition of fluid associated with both auriferous vein and remelted granite. The ore-bearing fluids are rich in CO_2 with low salinities (from early stage 7-9 wt % to later stage <1 wt % NaCl), and δD 71.3-82.6‰, $\delta^{18}O$ 2.7-7.33‰.

These data show: (1) Ore-bearing fluid is a [mixture of] magmatic and meteoric water; (2) the comparison between the I data in auriferous vein and in the remelted granite indicates [a] relationship of continuation and evolution; (3) the similar I data between auriferous quartz type and tectonic alteration type prove that these two types are products of the same mineralization but under different ore-controlled structural conditions.

In the light of other conditions, the authors suggest that the Archeozoic Jiaodong Group metamorphic volcano-sedimentary rocks (as a source of Au), granitization (as a dynamic force of Au migration) during regional metamorphism, and structural features are the three important factors of the mineralization event for this type of Au deposit.

Jiapigou Au Belt. The auriferous quartz veins are hosted in the Archeozoic Anshan Group which is a series of Au-bearing metamorphic basic-intermediate volcanic formations. This Au type is also important in China. The FI study for auriferous quartz and Anshan Group shows that they are very similar in composition. It indicates that the Anshan Group is the Au source bed, and [that the Au belt formed] at the later stage of the regional metamorphism of Archean.

The comparison of gas analysis between auriferous and unauriferous quartz indicates that the decrease of pH with the increase of CO_2 and decrease of T lead to the destabilization of Au complexes and thereby the deposition of Au.

Volcanic hydrothermal gold deposits. There is a specific geological setting for continental volcanic hydrothermal Au deposits in China, i.e., the volcanic belts related to Au mineralization always overlie or are adjacent to Au-bearing old metamorphic rock series. Compositions estimated for the fluids and I thermometry and barometry indicate that the mineralization event took place at 230-280°C, 0.4-0.6 kbar, [and] low salinity 4-6.3 wt % NaCl. The bulk compositions of gas are CO_2, H_2O, CH_4, $CO_2/H_2O = 0.3$-0.4; the liquid compositions are $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ and $F^- < Cl^- < SO_4^{2-}$ [sic], pH 5-7.1. SO_4^{2-} content [is] somewhat higher. Stable isotopic analysis of H_2O shows δD -58 to -91‰, $\delta^{18}O$ 5-10‰.

A model has been advanced and is consistent with these data and other geological conditions. It suggests that the later volcanic action or geothermal water heated the meteoric water up and dissolved Au and Ag from wall rocks. The fluid is rich in SO_4^- [sic]· showing that Au may migrate as $[AuS]^-$ or $[Au_2(HS)_2S]_2^-$ complexes. The deposition of Au is attributed to the destabilization of $[AuS]^-$ complex with the increase of fO_2 ($10^{-38.2} \rightarrow 10^{-35.7}$) and Eh (-0.65-0.60). (Authors' abstract)

Note: Paper not found in the Abstracts volumes from the 28th IGC. (E.R.)

CHENERY, S.R.N. and RANKIN, A.H., 1989, The use of laser ablation microprobe (LAMP) attached to an inductively coupled plasma spectrometer for the elemental analysis of individual fluid inclusions (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 21. Authors at Dept. Geol., Royal Sch. Mines, Imperial College, London, SW7 2BP, UK.

A knowledge of the composition of FI, especially their ore metal contents, is of profound importance to our understanding of the genesis of hydrothermal mineral deposits and for discriminant purposes in mineral exploration.

Analysis of bulk samples provides useful data. However, when multiple generations of inclusions are present it is desirable to analyze individual inclusions or small groups of inclusions. A variety of destructive and non-destructive microbeam methods have been investigated. These include electron, ion, proton and X-ray (synchrotron irradiation source) probes, laser-Raman, microspectrometry and laser ablation-mass spectrometry. To date the most successful methods are based upon EPMA/SEM techniques. Unfortunately, these are relatively insensitive to the low concentration of ore metals (<0.5%) likely to be encountered in most FI and to elements with low atomic numbers such as Li, B and Be.

The LAMP-ICPAES system offers an attractive alternative to established SEM/EPMA methods. Here we report on an exploratory study using a Carl Zeiss LMA-10 microprobe (with 1J Ruby laser) attached to an ARL 34000C ICPAES. The system is capable of simultaneous analysis of up to 40 elements from ablated material introduced into the Plasma via a stream of argon.

Investigations were carried out on opened and unopened, liquid-vapor and multiphase inclusions in quartz, topaz and fluorite. Initially, some difficulty was experienced in opening inclusions without shattering the specimen. But by manipulation of both the peak power and energy of the laser pulse we were able to restrict the size of the resulting laser crater down to the size of individual inclusions (100 µm). The best results were obtained on multisolid inclusions in topaz from a granite-hosted W deposit from New South Wales where we have been able to detect 15 or more elements including Na, K, Fe, Cu, Li, B, Be, V and, occasionally, important indicator elements such as Zn and As. These results were corroborated by SEM and optical identification of dms. At present, a number of uncertainties have yet to be resolved in the technique. However, by ratioing to Na and using synthetic FI as routine calibrant standards, the method offers considerable potential as a semi-quantitative method for the point analysis of certain elements in relatively large inclusion a few tens of micron below surface. (Authors' abstract)

CHINESE SOC. OF MIN., PETR., AND GEOCHEM., 1987, Experimental geochemistry: Papers from Chinese Second Nat'l Conf. on Fluid Inclusion Studies and Experimental Geochemistry, Guilin, Guangxi Province, Nov. 16-22 (in Chinese; the following titles from the Experimental Geochemistry part have been translated by H.-Z. Lu, and are in the order as listed).

1. Lin, Shengzhong et al., Phase equilibrium of monotropic reaction related to biotite.
2. Zeng, Yishan, Dickson equipment for hydrothermal reaction.
3. Li, Jiuling, Experimental study on Fe-Sb-Sn-S system.
4. Li, Zhaolin et al., Melting experiment of granodiorite porphyry, Ningzhen district.
5. Su, Lianghe et al., Experimental studies on ore magma.
6. Bai, Zhimin et al., Experimental research of Qianlishan granites under high P and T and the significance to petrology.
7. Li, Ying et al., Melting studies on Suzhou granite.
8. Zhou, Ruo, Melting and crystallization of granites under high P and T.
9. Zhou, Ruo et al., Experimental petrology of alkali basalts in Wudaliangchi district and adjacent region.
10. Wang, Liankui et al., Experimental investigation of Li- and F-bearing granites and their liquid separation from melt.
11. Huang, Shunhua et al., Experimental studies on geochemical features of REE elements in magmatism of granite.
12. Shi, Pingfang, The kinetics and thermodynamics of Sn mineralization.
13. Xu, Yongsheng, Experiments on partitioning of W between silicate melt and hydrothermal fluids.
14. Guo, Jide, Preparation of Sn-bearing granite gel.
15. Li, Pengjiu et al., Calculation of thermodynamic constants of Sn-bearing hydroxy complex and the forms of Sn migration.
16. Zeng, Jiliang et al., Preliminary studies on Sn partitioning between granitic magma and fluids.
17. Li, Tongjing, Experimental studies on solubility of cassiterite and extraction of Sn from granitic melt.
18. Liu, Yushan, The genesis of stannite in cassiterite sulfide mineral deposits.
19. Gao, Shan, The solubilities of scheelite and WO_3, and their significance on genesis of W mineral deposits.
20. Deng, Baolin et al., Experimental research on kinetics of alteration of wall rocks of Sn-W mineral deposits.
21. Han, Yingwen, The migration condition and forms of Mo in hydrothermal solution.
22. Yao, Lianying et al., Experimental investigation on deposition condition of molybdenite in Daheishan Mo porphyry deposit, Yongji county.
23. Wu, Houze et al., Synthetic fluid inclusions.
24. Wu, Houze et al., Experimental research on the solubility of cassiterite.
25. Fan, Yuqin et al., The mechanism of fractionation of S isotopes by bacteria and their significance to mineralization.

26. Wu, Houze et al., Migration form and ability of Pb and Zn under critical conditions.
27. Wu, Houze, et al., The forming conditions of Dabaoshan polymetallic deposit, Guangdong province.
28. Song, Chensheng, The RQV high speed quenching autoclave.
29. Liu, Zhengyi et al., Experimental studies of granite type U mineralization.
30. Shen, Caiqing et al., Synthetic uraninite and uranniobite and their conditions of formation.
31. Yao, Liangying et al., The solubility of uranniobite under low T and 1 atm.
32. Zhen, Yishan et al., Experimental studies of microcorrosion features on surface of quartz.
33. Wang, Yurong et al., The hydrolysis of coordinated complexes and their relationship to the thermodynamic behavior of water.
34. Cai, Yuanji, Experimental study of some geochemical features of chalcopyrite and melnikovite pyrite.
35. Zeng, Yishan et al., Determination of the solubility of hematite + magnetite assemblage in NaCl-H_2O solution under 300°C and 500 bars.
36. Li, Pengjiu et al., Estimate of the solubility coefficients of some minerals and inorganic materials in aqueous solution under high T.
37. Liang, Xianji, The characteristics and physico-chemical conditions of Na- and Al-bearing melilite formed by replacement.
38. Zhou, Mao et al., Experimental study on alteration from K-feldspar to kaolinite.
39. Yu, Yuanmei, Experimental study on aegirine syenite formed by replacement.
40. Ai, Ruiying, Experimental research on reaction between NaCl solution and magnetite quartzite.
41. Han, Yinwen et al., Pb and Sr partitioning between hydrothermal solution and barite and their application to geology.
42. Peng, Shenglin et al., Experimental study on the partitioning of Pb and Zn between granitic melt and hydrothermal fluid.
43. Ling, Wenli, The partitioning of Sr and Pb elements between barite and NaCl solution and their application to geology.
44. Liu, Yingjun et al., Experimental investigation on Au mineralization.
45. Jiang, Jingyie et al., Experimental research on migration of Au during metamorphism.
46. Fan, Wenling et al., Experimental studies on conditions of formation of native Au-Ag series minerals.
47. Wu, Ruihuan et al., Experimental investigation on improvement of color of natural sapphire.
48. Liang, Xiangji et al., The mechanism of the formation of Fe ore and metasomatite in sedimentary-metamorphic rocks.
49. Chen, Yaoting, An investigation of kinetics of decomposition of calcite.
50. Li, Pengjiu, Improvement of PHREEQR program used for calculation of geochemical equilibrium.

CHIODINI, Giovanni and **CIONI, Roberto,** 1989, Gas barometry for hydrothermal systems and its application to some Italian geothermal areas: Applied Geochem., v. 4, p. 465-472. First author at Dipartimento di Scienze della Terra dell'Universitá di Perugia, Piazza dell'Università, Perugia, Italy.

By the use of the CO_2, CH_4, H_2 and CO contents of geothermal gas discharges, the CO_2 partial P in the gas equilibration zone can be calculated.

Assuming that the partial P of water at any T are fixed by the presence of liquid water, then the following function, which is nearly independent of T, linking CO_2 partial P to the ratio XH_2/XCO is obtained:

$$\log PCO_2 = 3.573 - 46/T(K) - \log XH_2/XCO$$

Assuming a hydrostatic model, geothermal gradients for five high enthalpy and two medium to low enthalpy Italian geothermal areas have been estimated. High enthalpy systems can be clearly distinguished from those of low to medium enthalpy.

Finally, accurate determinations of the H_2/CO ratio in fluids discharged by selected fumaroles in volcanic areas can provide a method of monitoring P conditions in geothermal aquifers. This fact is particularly useful when the risk of a phreatic explosion in a volcanic area is to be assessed. (Authors' abstract)

CHIPLEY, D.B.L. and **KYSER, T.K.**, 1989, Fluid inclusion evidence for the deposition and diagenesis of the Patience Lake Member of the Devonian Prairie Evaporite Formation, Saskatchewan, Canada, *in* R.W. Renaut, ed., Sedimentology and Diagenesis of Evaporites: Sediment. Geol., v. 64, p. 287-295.

Low Br concentrations, radiometric ages, textural relations and large-scale dissolution and collapse features in Devonian potash deposits of the Elk Point Basin in southern Saskatchewan indicate that diagenetic processes and late influxes of water have variably recrystallized the salts. Lack of correlation between Th, δD and $\delta^{18}O$ values of FI in the salt with stratigraphic position further indicates that the sequence is not P. The stable isotopic compositions of FI waters, including those in chevron-texture halites, are not those expected for P crystallization waters and, in conjunction with Th, indicate recrystallization occurred at T of 35-70°C from water originating in formations above the Prairie Evaporite Formation. Using Th as an estimate of the depth of burial and stable isotopes as indicators of the source of fluids, three major recrystallization events related to the evolution of the Elk Point Basin can be recognized. (Authors' abstract)

CHMELKA, B.F.A and **PINES, A.**, 1989, Some developments in nuclear magnetic resonance of solids: Science, v. 246, p. 71-77. Authors at Lawrence Berkeley Laboratory and Univ. California, Berkeley, CA 94720.

Nuclear magnetic resonance (NMR) spectroscopy continues to evolve as a primary technique in the study of solids. This review briefly describes some developments in modern NMR that demonstrate its exciting potential as an analytical tool in fields as diverse as physics, chemistry, biology, geology, and materials science. Topics covered include motional narrowing by sample reorientation, multiple-quantum and overtone spectroscopy, probing porous solids with guest atoms and molecules, two-dimensional NMR studies of chemical exchange and spin diffusion, experiments at extreme T, NMR imaging of solid materials, and low-frequency and zero-field magnetic resonance. These developments permit increasingly complex structural and dynamical behavior to be probed at a molecular level and thus add to our understanding of macroscopic properties of materials. (Authors' abstract)

CHOU, Dingmao, 1989, The organogenic-diagenic origin of the Lixi type copper deposits: Geology and Prospecting, v. 25, (4), p. 23-25 (in Chinese).

Indexed under FI. (E.R.)

CHOU, I.M. and **CYGAN, G.L.**, 1989, Equilibrium and steady-state redox control in hydrothermal experiments (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-287.

CHOU, I-M. and **MOECHER, D.P.**, 1989, A new method for control and measurement of N_2 and NH_3 fugacities in hydrothermal experiments (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A155.

CHOU, I.-M. and **PASTERIS, J.D.**, 1989, High-density volatiles in the system C-O-H-N for the calibration of a laser Raman microprobe (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan 4-7, 1989, VPISU, Virginia], p. 18. First author at 959 National Center, U.S. Geol. Survey, Reston, VA 22092.

Three methods have been used to produce high-density volatiles in the system C-O-H-N for the calibration of a laser Raman microprobe (LRM): the synthetic FI, the sealed fused-quartz tube, and the high-P cell method. Because the quantitative interpretation of the Raman spectrum of mixed-volatile FI requires accurately known Raman scattering efficiencies (P-sensitive) for each species, calibrations of these parameters for mixtures of volatiles of known composition and P are necessary (Pasteris et al., 1988, Geochim. Cosmochim. Acta, 52, 979).

In the synthetic FI method, high-density volatiles, generated by thermal decomposition of suitable compounds in a sealed Au or Pt capsule, can be trapped as FI in prefractured quartz by following the general procedures outlined by Sterner and Bodnar (1984, Geochim. Cosmochim. Acta, 48, 2659). Two advantages of this method are that the inclusions can be used easily in complementary microthermometry (MT) studies and have sizes and optical properties like those in natural samples. Some disadvantages are that producing H_2O-free volatile mixtures is not possible, the composition may vary from one inclusion to another, the exact composition and density of the inclusions are difficult to obtain, and the experimental procedures are complicated.

In the sealed fused-quartz tube method, weighed amounts of suitable solids and (or) liquids are sealed in fused-quartz tubes, and the high-density volatiles are generated by thermal decomposition and chemical reactions (Kerkhof, 1988, PhD, Vrije Univ.). The advantage of this method is its simplicity. Some disadvantages are that the exact compositions for complex volatile mixtures are difficult to predict, the densities can be approximated only, because of relatively large uncertainties in tube-volume estimation, and, because of their large size and hence large T gradient, conducting complementary MT studies on the tubes is difficult.

In the high-P-cell method, known compositions of gas mixtures are pumped into the cell, which consists of a high-P valve fitted with a quartz window or connected to a fused-quartz tube. The total P of the sample is monitored by a P transducer or by a P gauge. Advantages of this method are that specific, known compositions of volatile mixtures can be produced and the total and partial P are monitored during calibration and can be varied easily. Some disadvantages are that complementary MT analysis is almost impossible and the setup is bulky. However, among the three methods described above for the calibration of an LRM, the high-P-cell method is most reliable and convenient in composition and total P control. (Authors' abstract)

CHRISTENSON, B.W., 1989, Fluid inclusion and stable isotope studies in the Kawerau hydrothermal system, New Zealand: Evidence for past magma-fluid interaction in the active system: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 155-158. Author at DSIR Geothermal Research Centre, Wairakei, New Zealand.

Comparison of present day measured T with fluid inclusion data show the main body of the hydrothermal system at Kawerau to have been thermally stable through time. $\delta^{18}O$ data from hydrothermal calcite are consistent with the stable thermal regime, but also reveal periods where isotopically heavy fluids were introduced into the system. It is proposed that these fluids were the result of direct magmatic interaction with the convecting reservoir. (Author's abstract)

CHRISTIE, A.B., GOGUEL, R.L. and **ROBINSON, B.W.,** 1989, Problems of crush—leach analyses of low-salinity inclusion-poor material: Chem. Geol., v. 78, p. 35-79. First author at New Zealand Geological Survey, DSIR, Lower Hutt, New Zealand.

We present analyses which suggest that single or multiple water leaches of low-salinity fluid inclusions are suspect and their application to chemical geothermometry is likely to give erroneous results.

Leaching experiments were conducted on 20 quartz and 1 calcite sample from epithermal veins in the Hauraki Goldfield, New Zealand, and 1 calcite drill-cutting sample from the Ngawha geothermal area. Each sample was crushed under vacuum in stainless-steel tubes and leached with a series of solvents. A three-stage leaching technique using H_2O, neutral-pH ammonium nitrate solution and 13% nitric acid solution was finally adopted. This process is designed to leach the fluid inclusions, remove ions adsorbed on the crushed mineral surfaces, and additionally indicate the presence of contamination from the host mineral and contained solid inclusions. Most of our analyses show contamination of Al, Ca, Li, Mg and, where analysed, Zn. A few are also contaminated by Na, K, Cl, Cs and Rb. Least contaminated analyses (11) indicate that the Hauraki epithermal fluids samples had salinities between 0.3 and 2.4 wt % with an average value of 1.0 wt %. (Authors' abstract)

CLAPSADDLE, Craig and **LAMB, Dennis,** 1989, The sorption behavior of SO_2 on ice at temperatures between -30°C and -5°C: Geophys. Res. Lett., v. 16, no. 10, p. 1173-1176. Authors at Meteorology Dept., The Pennsylvania State Univ., University Park, PA 16802.

Laboratory experiments explored the sorption behavior of SO_2 on ice between the temperatures of -30 and -5°C and with SO_2 mixing ratios of 15 to 95 ppb. The time-dependent data show clear evidence of two distinct exponential time constants and a dependence on SO_2 concentration. The equilibrium amount of SO_2 retained by the ice, determined by integration of the kinetic data, was found to increase strongly with T. The experimental results may be interpreted in terms of a disordered surface region which increases in thickness with T, enlarging the storage reservoir and generating the observed T dependence. (Authors' abstract)

Pertinent in gas analyses involving cryogenic separation. (E.R.)

CLARK, M.E., CARMICHAEL, D.M., HODGSON, C.J. and **FU, M.,** 1989, Wall-rock alteration, Victory gold mine, Kambalda, Western Australia: Processes and P-T-XCO_2 conditions of metasomatism, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: Econ. Geol. Monograph 6, The Economic Geol. Publ. Co., p. 445-459. First author at Western Mining Corp., 55 MacDonald St., Kalgoorlie, W. Australia 6430, Australia.

Au mineralization at the Victory mine, Kambalda, is associated with discrete metasomatic alteration zones around quartz breccia zones, shear zones, and quartz vein arrays. The mineralogy, textures, and whole-rock chemistry of the wall-rock alteration zones are described for several different host rocks. Mineral assemblages at zone boundaries, calcite-dolomite geothermometry, and amphibole geobarometry have been used to estimate the T, P and fluid composition associated with metasomatism. FI data have been used to estimate independently these conditions.

Assuming that local equilibrium conditions existed at alteration zone boundaries, mineral compositions from microprobe data have been used to model equilibria in the system SiO_2-Al_2O_3-MgO-CaO-K_2O-H_2O-CO_2. The mineral equilibria together with calcite-dolomite geothermometry provide an estimate of 390° ± 40°C for metasomatism which is similar to a minimum T estimate of 370° ± 30°C from FI data. Mineral equilibria and FI data suggest that pressure during metasomatism was ~1.7 to 2 kbars. FI data indicate that metasomatism was associated with a homogeneous H_2O-CO_2-NaCl fluid containing 19 to 36 wt % CO_2 $CX(CO_2) = 0.1$-0.2) and 8 to 9 eq. wt % NaCl.

The data presented in this study indicate that metasomatism occurred at considerably lower T and P than those estimated for peak metamorphic conditions at Victory. Thus after peak metamorphism, substantial uplift occurred before the hydrothermal emplacement of Au. (From authors' abstract by H.E.B.)

CLARKE, D.S., 1989, The trace element geochemistry of vein material in epithermal systems: Significance for exploration, *in* P.R.L. Browne and K. Nicholson, eds., Proc. 11th New Zealand Geothermal Workshop 1989, p. 139-141. Author at Epithermal Mineralisation Research Unit, Geology Dept., Univ. Auckland, Private Bag, Auckland, New Zealand.

Vein samples from the exploration for epithermal mineralisation are commonly subjected to multi-element analysis. Trace element geochemical response in such material is a recognisable characteristic of epithermal mineralisation, and provides a routine "fingerprinting" method. In this role, however, vein geochemistry should only complement, not be a substitute for, morphologic and textural observations. Vein geochemistry is not convincing as an indicator of vertical zonation within a mineralised structure; alteration and fluid inclusions studies are more useful in such assessments. (Author's abstract)

CLAUER, Norbert, FRAPE, S.K. and **FRITZ, Bertrand,** 1989, Calcite veins of the Stripa granite (Sweden) as records of the origin of the groundwaters and their interactions with the granitic body: Geochim. Cosmochim. Acta, v. 53, p. 1777-1781.

CLAYTON, R.N., GOLDSMITH, J.R. and **MAYEDA, T.K.,** 1989, Oxygen isotope fractionation in quartz, albite, anorthite and calcite: Geochimica Cosmochim. Acta, v. 53, p. 725-733. First author at Enrico Fermi Inst., Dept. Chem. and Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637, USA.

Laboratory measurements of equilibrium O isotope fractionation in quartz, albite, anorthite, and calcite have been carried out by anhydrous exchange between silicates and calcite at 600°C and above. Exchange in these systems is as rapid as exchange between silicates and water. Fractionation factors can be summarized in the following equations: $\Delta QC = 0.38 \bullet 10^6T^{-2}$; $\Delta AbC = -0.57 \bullet 10^6T^{-2}$; and $\Delta AnC = -1.59 \bullet 10^6T^{-2}$, from which the silicate-pair fractionations are readily obtained. These results are compared with published theoretical estimates as well as data derived from hydrothermal experiments. Some significant differences are found. In particular, it is difficult to reconcile all of the hydrothermal data either with theoretical calculations or with the present experimental data. The new experiments provide an internally consistent set of fractionation factors suitable for isotopic thermometry and for test of disequilibrium in natural systems. (Authors' abstract)

CLINE, J.S. and BODNAR, R.J., 1989a, Genesis of epithermal gold deposits: A numerical model for silica and gold transport in boiling hydrothermal systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-303-304.

CLINE, J.S. and BODNAR, R.J., 1989b, Partitioning of Cu and Cl in magmatic/hydrothermal systems: Application to the Yerington, Nevada, porphyry deposit (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A150. Authors at Dept. Geological Sciences, Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Numerical simulation of Cl and Cu partitioning between a crystallizing melt and exsolving aqueous fluid indicates "typical" calc-alkaline magmas contain sufficient Cu to produce economic porphyry Cu mineralization. Neither an elevated Cu content in the magma nor significant additional magma "at depth" are required to provide metals or volatiles. Cu mineralization is produced most efficiently by earliest exsolving fluids in deep (2.0 kb) systems and late exsolving fluids in shallow (0.5 kb) systems. Melts crystallizing extensively prior to water saturation may lose >80% of their initial Cu to crystallizing minerals. The bulk salinity of the exsolved fluid may vary from <2.0 wt % to >70 wt % NaCl, indicating boiling is not necessary to produce high salinity brines. At appropriate P-T-X(NaCl) conditions, the exsolving fluid separates into a saline liquid, which transports most of the Cu, and a low-salinity vapor. The salinities of the two immiscible phases are governed by the P-T conditions, while the bulk fluid salinity determines the mass fractions of liquid and vapor formed. At intermediate P (~1.0 kb), increasing Cu in the fluid coincides with decreasing salinity resulting in formation of a large vapor fraction which transports up to 20% of the Cu in solution.

Model results, incorporating published petrologic constraints for porphyry Cu mineralization at Yerington, Nevada, show good agreement with observations. Cu is associated with intrusion of the Luhr Hill porphyritic granite and related dikes. Phase petrology and mineral compositions indicate the intruding magma was within 1% of water saturation and that crystallization and cooling to ~750°C at 1.1 kb led to saturation and exsolution of ~3 wt % water. A porphyritic texture suggests that after 50% crystallization the system was P quenched. Model results indicate that quenching abruptly reduced the amount of Cl and Cu partitioning into the exsolving aqueous fluid and that P fluctuations produce porphyry fluids with distinctly different salinities. In response to reduced partitioning of Cl and Cu to the aqueous phase, concentrations of both elements in the melt increase as the remaining melt crystallizes and the final exsolved fluids contain elevated concentrations of both elements. The model predicts ~77 km^3 of magma is necessary to produce the 6 million tons of Cu present at Yerington. This is in good agreement with an exposed (minimum) volume of ~65 km^3 of Luhr Hill granite. (Authors' abstract)

CLOCCHIATTI, R. and **TOURET, J.L.R.**, 1989, Fluid and saline melt inclusions in Zabargad (St. John) peridotites (abst.): 28th Int'l Geol. Cong. Abstracts, p. 304. First author at Groupe Sciences de la Terre, CEN Saclay, France. [Paper not presented at Congress. E.R.]

Known since antiquity for its idiomorphic, gem olivines, the peridotitic massif of Zabargad (Egypt) corresponds to a slice of upper mantle emplaced in the continental crust during early rifting of the Red Sea (1). It consists of three separate bodies (Northern, Central and Main Peridotite Hills, respectively) which are made of spinel lherzolite, amphibole, and plagioclase peridotite. They have developed at their contact high grade metamorphism in sediments of unknown age. The metamorphism and hence the high T emplacement of the peridotite has been dated as early Miocene, close to the deposition of the middle to upper Miocene evaporite unit which lies unconformably above the peridotites.

Olivine and pyroxenes of the various peridotite types contain an unusual variety of inclusions, most of them S. They fall basically into two major groups:

Group A: Most abundant inclusions are CO_2 rich, with Th(L) between 0°C and ~+20°C. They occur in trails and contain frequently solid dms of various size (magnesite, dolomite, calcites, quartz, plagioclase). There is a distinct relation between the nature of most abundant dms and the host minerals: magnesite and quartz in olivine and orthopyroxene, dolomite, calcite, quartz and plagioclase (in this order) in clinopyroxene and amphibole. These inclusions are comparable to fluids found in many ultrabasic xenoliths and they are undoubtedly of deep, upper mantle origin. For a reference T of 1000°C, likely to have been preserved until near surface conditions, the highest CO_2 density would indicate a maximum P of 6 kb (18 km depth).

The content of *group B inclusions*, which are less abundant and much more unusual than the preceding ones, is exclusively solid at room T, with an irregular gas bubble of various size. They contain a most complicated assemblage of various salt melts (Na, K, Ca and Fe chlorides and sulfates), in which many minerals may occur: Mg, Fe, Ca carbonates, Fe, Ni sulfides, Fe, Cr, Al-spinel, unidentified Fe-Mg silicates. The gas bubble is either empty, or low density CO_2 or N_2 (Th(V) for CO_2 between +17 and +30°C, for N_2 between -147 and -170°C).

Group B inclusions are well represented in various monomineralic segregations, notably in the gem olivine which occur as loose crystals in partly serpentinized veins or in open, mariolitic cavities. The saline fluids seem to be able to percolate through relative large rock masses, and they could be responsible for the conspicuous metasomatic effects reported in the peridotites (3). They are well separated from group A inclusions in time and space. There are some indications suggesting that they could, at least partly, postdate group A inclusions.

The origin of group B inclusions is most problematic. In the present stage of our knowledge, a mobilization or back veining of evaporites formed during the initial rifting cannot be excluded. But most evaporites found in the region are definitely younger and lying unconformably on the peridotite. Similarities between group B inclusions and inclusions occurring in some carbonatites (e.g., 4) might indicate a deeper, mantle derived origin. More information, notably stable isotope data, are clearly needed for a better understanding of these strange inclusions.

References: (1) Bonatti et al., 1986, J. Geophys. Res., 91, B1, 599-631. (2) Nicolas et al., 1987, J. Geophys. Res., 92, 461-474. (3) Kurat et al., 1983, EUG II, Strassbourg (Abst.). (4) Rankin et al., 1974, Min. Mag., 39, 563-570. (Authors' abstract)

CLOCCHIATTI, Roberto and **WEISZ, Jacqueline**, 1989, Bocca Nuova (Mt. Etna) magma supply in September 1988. Some considerations from the chemical composition of magma trapped during a salite-diopside crystal growth: C. R. Acad. Sci. Paris, v. 309, ser. II, p. 253-258 (in French, English abstract).

Changes with time in salite-diopside composition of a single crystal, related to trapped melt compositions, point out the presence, in Mt. Etna output, of at least two magmas. The first one, of hawaiite-mugearite, partially degassed composition (S = 1200-300 ppm; Cl = 4000-1500 ppm, $H_2O < 3\%$) is similar to melts trapped in minerals from eruptions subsequent to 1983. The second one, of alkali basalt hawaiite composition, recently intruded in the volcano supply, is characterized by a high content in volatile elements (S = 3000-2500 ppm; Cl = 2500-2000 ppm; $H_2O > 3\%$), similar to that measured in glass inclusions of some minerals from 1669, 1763 and 1892 eruptions. Sulphur and chlorine contents in both magmas are discussed. (Authors' abstract)

COELHO, C.E.S., TOURAY, J.C., BENY, C. and **GIULIANI, G.**, 1989, Quartz fabrics and fluid inclusions volatiles at Fazenda Brasileiro gold mine: A preliminary petrographical and Raman microprobe study (abst.) Symposium GEORAMAN 89, Toulouse, France, 17-19 May 1989, Abstracts (unpaginated). Also in Bull. Liason Soc. Franc. Mineral. Crist., v. 2, no. 1, p. 23 (1990). First author at Dept. Nacional da Produção Mineral, Divisão de Geologia et Mineralogia, Brazil/Ecole Supérieure de l'Energie et des Matériaux, Université d'Orléans, Laboratoire de Métallogénie et Géochimie, Orléans 45067 Cedex 2, France.

Fazenda Brasileiro Au mine is located in the northeastern part of Bahia State, Brazil, within a 8 km E-W shear zone (Weber Belt), in the mafic domain of the "Rio Itapicuru" Greenstone Belt. It is an early Proterozoic auriferous quartz-lode deposit, hosted in Fe-rich sheared chloritic schists (Santos et al., 1988).

Shear deformation during greenschist facies metamorphism (F1) produced a thick mylonite zone generating a high permeability path. Au deposition occurred along this ductile shear zone, mainly during a F2 ductile-brittle deformation stage (Reinhardt and Davison, 1988). Raman spectroscopy analyses of ~50 fluid inclusions were made in five mineralized quartz-vein samples according to the structural evolution of the mine.

According to quartz fabrics the fluid inclusions may be broadly divided in two groups: (a) those situated in residual phenoclasts of quartz immersed in a recrystallized matrix; and (b) those related to the own recrystallized quartz grains (localized within and in the boundaries of the neograins and in nucleation centers inside phenoclasts), which are observed in all samples.

The "early" stage inclusions can be subdivided in four types: type I CO_2-CH_4-N_2 usually C-bearing; type II CO_2-CH_4 frequently C-bearing; type III CO_2; and type IV CH_4-N_2-(H_2O). Water was not observed when type I fluid inclusions are associated with graphite; it may have been lost after trapping either by diffusion (Roedder, 1984) or by in situ reactions (Dubessy, 1984); alteratively, water contents may have been larger than estimated from microscopic observations (Kreulen, 1987).

Later inclusions, related to recrystallized quartz, apparently do not contain graphite and have higher water proportions; in addition to the composition range in earlier inclusions (types I, II and IV), one notices the presence of type V CH_4-(H_2O) inclusions and the lack of type III CO_2 ones. Types IV and V are sometimes in S trails crosscutting recrystallized quartz. Later H_2O rich inclusions are present in all samples, mainly along healed fractures. In fluid inclusion studies carried out on three mineralized samples from the mine by Xavier (1987), distinction between inclusions belonging to phenoclasts and recrystallized quartz was not observed neither C-bearing inclusions [sic].

Two main episodes of the hydrothermal evolution may be illustrated: (1) Early CO_2-CH_4-N_2 and CO_2-CH_4 usually C-bearing fluid inclusions in phenoclasts may indicate an earlier circulation in a hot low-density fluid probably equilibrated with graphitic pelites during metamorphism, reflecting fluid compositions during the brittle-deformation of quartz (F2); and (2) the inclusions observed in the recrystallized quartz could result from the mixing of the former volatiles with aqueous fluids.

Type I inclusions from recrystallized quartz appear spatially related to auriferous sulfides and free Au; hence, they probably represent the ore-forming fluids. Fluids trapped in phenoclasts are not considered to have played a role in the genesis of the mineralization and are thought to be metamorphic volatiles older than Au deposition.

The model proposed for the ore genesis is related to the destabilization of soluble Au complexes in relatively oxidized fluids that would rise along the ductile shear zone, when it became reduced by interaction with graphitic pelites that rest structurally above the mineralized zone. Above 400°C (the minimum Tt of type I fluid inclusions recorded by Xavier, 1987), the fluid maintained its fO_2 close or above the Q-F-M buffer, compatible with the graphite-fluid equilibrium (Kreulen, 1987). Au deposition may have taken place when the graphite-fluid equilibrium was no longer maintained. Fluctuations of T around the blocking T of the graphite-fluid equilibrium (Ramboz et al., 1985) could have caused repeated stages of Au deposition, possibly during all the period of ductile-brittle deformation (F2). (From authors' abstract by E.R.; references omitted)

COETZEE, D.S., ROERING, C. and VAN REENEN, D.D. 1989, Microthermometric evidence of variable metamorphic conditions in the Witwatersrand Basin, South Africa (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 22. Authors at Dept. Geol., Technikon Pretoria, 420 Church St., Pretoria 0002, South Africa.

Results of metamorphic and FI studies of the Witwatersrand Basin are reported. The Witwatersrand Basin situated in the Southern Transvaal, South Africa, has traditionally been regarded as undeformed and unaffected by metamorphism.

It was, however, recently revealed that the Witwatersrand has been subjected to deformation of a magnitude which has previously not been anticipated within the confines of the Witwatersrand Basin. Several imbricated zones of thrust slices situated along the northern rim of the Witwatersrand Basin are clearly related to a single major thrusting event, and they are all characterized by the presence of well developed metamorphic rocks including several types of phyllonites, mylonites, pseudotachylite and a variety of cataclasites, as well as associated syntectonic quartz veins.

The widespread occurrence of quartz, kaolinite, pyrophyllite and kyanite together with accessory sericite, chlorite and iron oxides allows the delineation of zones of variable metamorphic grade, ranging from zones of low grade metamorphism to zones of greenschist facies metamorphism, within the Witwatersrand Basin.

A systematic variation in the complex fluid composition and salinity of inclusion fluids from syntectonic vein quartz, correlates very well with variable metamorphic grade as predicted by petrogenetic evidence.

Inclusion fluids associated with areas of higher metamorphic grades are either CO_2-rich or highly saline, whereas those associated with lower metamorphic grades contain little or no CO_2 and appreciable amounts of hydrocarbons, and are less saline. These results correspond very well with results obtained from late stage fluids from metamorphic belts elsewhere in the world. (Authors' abstract)

COETZEE, Japie and TWIST, David, 1989, Disseminated tin mineralization in the roof of the Bushveld granite pluton at the Zaaiplaats mine, with implications for the genesis of magmatic hydrothermal tin systems: Econ. Geol., v. 84, p. 1817-1834. Authors at Inst. for Geological Research on the Bushveld Complex, Univ. Pretoria, 0001 Pretoria, South Africa.

For the most part, the Bushveld granites are not metallogenically specialized in the manner of other tin mineralized plutons. Late saturation and exsolution of a Cl-rich fluid represents by far the major process responsible for the Zaaiplaats deposits and other endogranitic tin ores. At Zaaiplaats, the ore minerals crystallized at high T from relatively saline fluids that exsolved into interstitial pore spaces in the cooling crystal mush. This process formed an intrinsic part of the normal cooling history of the pluton, illustrating that the Bushveld granites define a temporal continuum between magmatic crystallization, fluid exsolution, and water-rock reaction. (From authors' abstract by E.R.)

COHEN-ADAD, Roger, COHEN-ADAD, M-T.S. and OUAINI, Rosette, 1990, Choice of a model for calculation and critical evaluation of solid-liquid electrolyte phase diagrams. Application to the ternary system NaCl-KCl-H_2O: Pure & Appl. Chem., v. 62, no. 1, p. 1-7. Authors at Univ. Lyon I, Laboratoire de Physico chimie Minérale 2, URA CNRS 116, 69622 Villeurbanne Cédex, France.

In order to find expressions for fitting equations that could be applied to any type of electrolyte phase diagram and easily extended from binary to ternary systems, we were led to proceed in two steps: first, find fitting equations for solubilities along convenient isoplethic sections of the diagram, and second, extend the calculation to isothermal sections. The model is applied to the calculation of solubilities in the ternary system NaCl-KCl-H_2O. (Authors' abstract)

COLE, D.R. and WESOLOWSKI, D.J., 1989a, Influence of NaCl aqueous solutions on isotopic equilibria and rates of exchange in mineral-fluid systems: Geothermal Resources Council, Trans., v. 13, p. 227-234. Authors at Chemistry Div., Oak Ridge Nat'l Laboratory, Oak Ridge, TN 37831.

The effect of NaCl aqueous solutions on the rates of isotopic exchange and fractionation factors between minerals and fluids has been evaluated at elevated T using the available experimental data. Rates of O isotopic exchange are significantly increased by interaction of a solid with NaCl solutions. For example, the rate of granite-H_2O oxygen isotopic exchange is $10^{-9.45}$ moles 0 m^{-2} sec^{-1} at 200°C, but $10^{-7.75}$ for granite-0.5 m NaCl interaction. The durations required to attain 90% isotopic exchange in the granite-fluid system have been calculated using a modified surface-exchange rate model (Cole et al., 1983). These calculations indicate that granite-pure water interaction requires ~3700 years to reach 90% exchange, but only 74 years for reaction with 0.5 m NaCl at 200°C [grain radius = 0.1 cm, $(W/R)_{mass} = 1$].

Isotopic fractionation factors between minerals and aqueous NaCl solutions can differ significantly from the mineral-pure water values. The salt effect can be as large as 2 to 3.5‰ for O and 12‰ for H at >150°C. If ignored, the salt effect associated with 4 m NaCl solution can lead to maximum error in geothermometer estimates for O of 35°C in the quartz-fluid system, and 50°C for H in the kaolinite-fluid system. The magnitude of these salinity effects is far too great to be ignored and must be accounted for when modeling isotopic exchange in hydrothermal systems. (Authors' abstract)

COLE, D.R. and WESOLOWSKI, D.J., 1989b, Oxygen and hydrogen isotope partitioning between water liquid and vapor at elevated temperatures: Geothermal Resources Council, Trans., v. 13, p. 235-240. Authors at Chemistry Div., Oak Ridge Nat'l Laboratory, Oak Ridge, TN 37831.

O and H isotope fractionation factors ($\alpha^{O}_{l\text{-}v}$ and $\alpha^{D}_{l\text{-}v}$ between liquid water and water vapor have been calculated from vapor P ratio measurements and equations of state over the range 0 to 370°C. These data are compared to the liquid-vapor fractionation factors determined by direct mass spectral measurements. The values for $\alpha^{D}_{l\text{-}v}$ derived from the vapor P ratios are in close agreement with the experimental mass spectral measurements from 0 to 300°C when fugacity coefficient and molar volume corrections are used. Deviations from the direct measurements above 0 to 300°C are due to inadequacies in either (1) the magnitude of the molar volume correction for D_2O near the critical point, (2) the assumption of ideal mixing of the isotopic gases and liquids, and/or (3) the selection of 1.91 as the disproportionation factor for the formation of HDO. On the other hand, the $\alpha^{O}_{l\text{-}v}$ values derived from vapor P data (no fugacity or molar volume corrections) agree closely with low-T direct measurement data, pass through some of Bottinga's (1968) high T results, and extrapolate smoothly to $\alpha^{O}_{l\text{-}v}$ at the critical T as is required by thermodynamics. This behavior coupled with the fact that Bottinga's (1968) O isotope results exhibit a large scatter, indicates that liquid-vapor O isotope fractionation factors based on vapor P measurements should be applied to high-T geothermal systems rather than the direct mass spectral data. (Authors' abstract)

COLLAO, S.I., 1988, Fluid inclusions in ore bodies and surrounding rocks from the metamorphic basement of southern Chile (abst): Communicaciones, Una Revista de Geologia Andina (Communications, a Review of Andean Geology), 5th Geological Congress of Chile, Spec. Issue No. 39, p. 50 (in Spanish).

Fluid inclusions in quartz crystals formed during and after metamorphism [event or process] have been studied in ore bodies and surrounding rocks of massive sulfide deposits in greenschists, barren metacherts, and manganiferous-metacherts of the Tirua unit, and in ferruginous metacherts (banded iron formations)-mica schists of the Nahuelbuta unit (Formation). The microthermometry study of the two-phase fluid inclusions (L + V) indicate the range in Th in general are: in massive sulfide-greenschist rocks, between 200° and 450°C, in manganiferous metacherts and barren metacherts ranges between 144° and 410°C, and in ferruginous metacherts-mica schists, between 188° and 478°C. These ranges are relatively similar and reflect the regional maximum and decreasing T that occurred respectively during and after regional metamorphism. The fluid phase composition varies between 2 and 15 eq. wt % NaCl, with the highest values corresponding to the massive sulfides-greenschist rocks. (From authors' abstract, translated by G. Landis)

COLSON, R.O., 1989, A reaction relationship between two nepheline syenites from Magnet Cove, Arkansas, possibly related to immiscible separation of carbonatitic magma (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A326.

CONCEPCION, R.A. and **CINCO, J.C.**, 1989, Geology of Lepanto far southeast gold-rich porphyry copper deposit, Mankayan, Benguet, Philippines (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-319-320. Authors at Lepanto Mine Division, Lepanto, Philippines.

By global standards, this deep-seated Au-rich deposit is world-class. It is genetically related to a Late(?) Miocene quartz diorite stock that intruded the Middle Miocene Balili Volcaniclastics. Preliminary fluid inclusion studies indicate an average Th of 529°/ppm 80°C. (From authors' abstract by E.R.) [sic; see p. 1]

CONNOLLY, C.A., 1989, Thermal history and diagenesis of the Wilrich Member shale, Spirit River Formation, northwest Alberta: Bull. Can. Petrol. Geol., v. 37, no. 2, p. 182-197. Author at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

A well-defined trend of increasing maximum paleotemperatures from 100° to 107°C from east to west is determined using three independent methods: clay mineral determinations, vitrinite reflectance, and geothermal gradient-maximum depth. (From authors' abstract by E.R.)

CONNOLLY, C.A., WALTER, L.M., BAADSGAARD, H. and **LONGSTAFFE, F.J.**, 1989, Geochemical and isotopic composition of Paleozoic and Mesozoic formation fluids in the western Canada sedimentary basin (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-14. First author at Dept. Geol., Univ. Alta., Edmonton, Alta. T6G 2E3, Canada.

Fifty oil field waters produced from Devonian through Cretaceous reservoir rocks in the western Canada sedimentary basin, south-central Alberta, were analyzed for chemical and isotopic ($^{18}O/^{16}O$; D/H; $^{87}Sr/^{86}Sr$) compositions. Formation waters are predominantly Na-Cl brines (4 to 235 g/l TDS), increasing in concentration with age of the formation rather than depth. Lithologic units from which the fluids were sampled can be subdivided into a Devonian through Jurassic carbonate and evaporite assemblage and a Cretaceous clastic sequence. The clastic assemblage has anomalous Ba concentrations and exhibits higher fluid Na/K and Na/Ca ratios and lower K/Br ratios than the carbonate sequence. Organic acids (acetate, propionate, and butyrate) are prevalent (50 to 900 mg/l) in isolated formations above the Devonian and correlate inversely with Br. Conservative element data (e.g., Na vs. Ca) suggest that many of these samples are mixtures of two or more brines diluted by meteoric water. Mixtures and end member solutions are more clearly discriminated when brines are grouped stratigraphically. H_2S-rich brines are found in both carbonate- and clastic-hosted fluids and exhibit up to three times higher concentrations of Sr, Li, B, Ca, and SO_4^{-2} and up to five times lower concentrations of Ba than fluids lacking H_2S.

Strontium concentrations are variable with no distinct trends or differences between the carbonate and clastic assemblages. Fluids in lowermost Devonian formations ($^{87}Sr/^{86}Sr = 0.7083-0.7097$) are similar to seawater values at the time of deposition. Most Mississippian through mid-Cretaceous brines have Sr ratios higher than the corresponding seawater values, whereas post mid-Cretaceous Sr ratios (0.7086-0.7055) are lower than corresponding seawater values. Isotopic analyses of reservoir cores show that the rocks are not in equilibrium with brines. All fluid samples plot on a linear trajectory off of the meteoric water line (GMWL) on a $\delta^{18}O$ vs. δD plot with more dilute samples closer to the GMWL. Mixing of brines with meteoric water in varying degrees is indicated. D/H and $^{87}Sr/^{86}Sr$ ratios show distinct *inter*-formational variations, but little *intra*-formational variability, indicating extensive lateral migration of fluids. (Authors' abstract)

CONSTANTOPOULOS, J.T., 1989, Oxygen and isotope geochemistry of the Coeur d'Alene mining district, Idaho: PhD dissertation, Univ. Idaho.

Indexed under FI. (E.R.)

COOK, C.W., 1979, Fluid inclusions and petrogenesis of the Harding pegmatite, Taos County, New Mexico: MS thesis, Univ. New Mexico.

The Harding pegmatite, Taos County, New Mexico, is a complex zoned Li-rich pegmatite which exhibits extensive replacement mineralization. Beryl and quartz, found in all pegmatite zones, contain abundant FI which allow determination of pegmatite fluid composition and conditions of pegmatite formation by FI analytical methods.

P FI average 15 wt % CO_2 and 15 eq. wt % NaCl. Th for the wall zone, massive quartz zone and quartz-lath spodumene zone fall in the range of 300° to 375°C. S FI contain little or no CO_2 and average 30 eq. wt % NaCl. Th for S FI are near 90°C.

Single-phase CO_2 fluid densities and stable isotope thermometry indicate initial crystallization of the wall zone at 525° ± 50°C and at 2.25 ± 0.25 kb (6.0-7.5 km). All primary zones crystallized from a magma in contact with an aqueous volatile-rich fluid. Late stage P releases formed sugary albite units by P quenching and prevented formation of pocket pegmatite. Residual magma formed cleavelandite replacement bodies. Late stage hydrothermal Li replacement features were caused by Li-rich saline brines near 300°C. Final mineralization at the Harding pegmatite occurred at 248 ± 25°C. (From author's abstract)

COOL, E.G., 1989, Vein formation, fluid flow and wall rock geochemistry at the Lucky Friday Mine, Coeur d'Alene mining district, Idaho (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-323-324. Author at Woodward-Clyde Consultants, Wayne, NJ.

Stable isotope ratios of the carbonate minerals suggest that the wall rock fluid was dominantly water. Fluid inclusions and calcite-dolomite geothermometry (corrected for ankerite) yield peak metamorphic temperatures of ~275° to 325°C.

The proposed mechanism for precipitation of the Lucky Friday vein is the mixing of a deep, hypogene fluid, with the fluid derived from the wall rocks. Stratiform sulfide deposits, which occur elsewhere in Belt Supergroup rocks, may represent a source for the ore constituents. Although the origin of the individual ore constituents can not be specified, the mixing of two fluids at the ore horizon may have effectively caused the precipitation of the vein. (From authors' abstract by E.R.)

COONEY, T.F., 1989, Evidence for immiscibility in ultrabasic melts (abst.): Eos, v. 70, p. 488. Author at Hawaii Inst. Geophys., Univ. of Hawaii at Manoa, 2525 Correa Rd., Honolulu, HI 96822.

Crystalline quench products from high-T strip-melting experiments using natural olivine (approximate composition Fo90) as a starting material exhibit knife-sharp interfaces separating regions of contrasting composition. Taken together with evidence for globule coalescence and meniscus development at relict vapor bubbles, the overall forms of these interfaces provide clear evidence for the coexistence of two liquids in these experiments. Both liquids formed pyroxene as one of the quench products because the bulk composition was driven towards silica by preferential volatilization of MgO and FeO relative to SiO_2. The proportion of quench pyroxene is the main compositional discriminant between the two quenched melts. The proposed immiscibility is not likely to have played any petrogenetic role within the time span encompassed by the rock record. Nonetheless it may have played a limited role in the primordial differentiation of the mantle if a terrestrial magma ocean ever existed. (From author's abstract by E.R.)

CORDIER, Patrick and **DOUKHAN, J-C.**, 1989, Water solubility in quartz and its influence on ductility: Eur. J. Mineral., v. 1, p. 221-237. Authors at Lab Struct. et Prop. de l'Etat Solide (associé au CNRS no 234), Univ. Lille-Flandres-Artois, 59655 Villeneuve d'Ascq Cedex, France.

The deformation of wet synthetic quartz at moderate T is accompanied by a continuous change of the state of dispersion of H_2O (precipitation); other relevant parameters of the deformation process like flow stress or strain hardening are affected by this phenomenon. We have characterized experimentally the solubility of H_2O in quartz as a function of P at a given T (700°C). Wet samples have been annealed at this T and under various confining P; then they have been observed by TEM to check if H_2O had precipitated or not. We find that the solubility increases with P and reaches a value of 50 to 100 at. ppm at 800 MPa. We then deformed wet quartzes with a homogeneous H_2O content at T,P conditions such that, in one case, it was lower than the equilibrium concentration while, in the other case, it was only slightly larger. Only glide is observed in the first case while in the supersaturated crystals, dislocation climb in the prominent feature at the same T,P and ε deformation conditions. (Author's abstract)

CORTECCI, G., FONTES, J.Ch, MAIORANI, A., PERNA, G., PINTUS, E. and **TURI, B.**, 1989, Oxygen, sulfur, and strontium isotope and fluid inclusion studies of barite deposits from the Iglesiente-Sulcis mining district, southwestern Sardinia, Italy: Mineral. Deposita, v. 24, p. 34-42. First author at Dipart. di Sci. della Terra, Univ. di Pisa, Via Santa Maria 53, I-56100 Pisa, Italy.

This paper deals with barite from stratiform, karst, and vein deposits hosted within Lower Paleozoic rocks of the Iglesiente-Sulcis mining district in southwestern Sardinia. For comparison sulfates from mine waters are studied. Stratiform barite displays $\delta^{34}S = 28.8\text{-}32.1‰$, $\delta^{18}O = 12.7\text{-}15.5‰$, and $^{87}Sr/^{86}Sr = 0.7087$, in keeping with an essentially Cambrian marine origin of both sulfate and Sr. Epigenetic barite from post-Hercynian karst and vein deposits is indistinguishable for both S and O isotopes with $\delta^{34}S = 15.3\text{-}26.4‰$ and $\delta^{18}O = 6.6\text{-}12.5‰$; $^{87}Sr/^{86}Sr$ ratios vary 0.7094-0.7140. These results and the microthermometric and salinity data from FI concur in suggesting that barite formed at the site of mineralization by oxidation of reduced S from Cambrian-Ordovician sulfide ores in warm, sometimes hot solutions consisting of dilute water and saline brine with different $\delta^{18}O$ values. The relative proportion of the two types of water may have largely varied within a given deposit during the mineralization. In the karst barite Sr was essentially provided by carbonate host rocks, whereas both carbonate and Lower Paleozoic shale host rocks should have been important sources for Sr of the vein barite. Finally, $\delta^{34}S$ data of dissolved sulfate provide further support for the mixed sea water-meteoric water composition of mine waters from the Iglesiente area. (Authors' abstract)

COVENEY, R.M., Jr. and **GLASCOCK, M.D.**, 1989, A review of the origins of metal-rich Pennsylvanian black shales, central U.S.A., with an inferred role for basinal brines: Applied Geochem., v. 4, p. 347-367. First author at Dept. Geosciences, Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

Compared to most shales, even most black shales, numerous thin Pennsylvania marine black shales of the U.S. Midwest are very enriched in organic C (>5-40 wt %) and heavy elements. For example, instrumental neutron activation analysis of 74 samples of mostly black and dark gray Pennsylvanian shales of the U.S. Midwest average 1300 ppm Zn, 85 ppm U, 655 ppm Mo, 130 ppm Se and 55 ppm Cd—amounts sufficient to raise concerns about heavy element pollution. Direct precipitation of sulfides and fixation by abundant organic matter during sedimentation and early diagenesis may account for heavy metals contained by shales in most cases. Metal supply calculations, however, indicate that a special source would be needed to supply metals for a strictly syngenetic origin. Possible sources for such metals include submarine hot springs and Pennsylvanian seas that may have been more enriched in metals than modern ocean water. At least at some localities, additional metal values may have been added later from basinal brines (e.g. Zn) or from modern groundwaters (e.g. Mo, Se, U). The actions of modern supergene processes may fix metals, mitigating detrimental effects from black shales. (Authors' abstract)

CRAW, D., 1989, Shallow-level, late-stage gold mineralisation in Sawyers Creek, Shotover valley, northwest Otago, New Zealand: New Zealand J. Geol. and Geophys., v. 32, p. 385-393. Author at Geology Dept., Univ. Otago, P.O. Box 56, Dunedin, New Zealand.

A set of mainly west and northwest-striking normal faults in Sawyers Creek, Shotover valley, crosscuts post-Oligocene Moonlight Generation structures. These faults have provided access for hydrothermal fluids to shallow crustal levels. Silicification and carbonate alteration of breccias and wall rock has occurred, to form reef zones up to 3 m wide. Au is found with pyrite and arsenopyrite within the siliceous portions of the reef, especially at fault intersections. The hydrothermal fluid was water with minor dissolved CO_2. Mineralisation occurred at ~150-200°C at 2-3 km depth. Wall-rock interaction with the fluid caused replacement of chlorite by ankeritic carbonate. The composition of the ankerite is governed by the composition of the chlorite it replaced. Fluid reaction with chlorite caused the fluid to become progressively more alkaline which eventually resulted in precipitation of Au. Similar fluid activity, in similar structural settings, is found throughout northwest Otago. (Author's abstract)

CRAW, D., JOHNSTONE, R.D. and RATTENBURY, M.S., 1989, Tectonic-hydrothermal Au-Cu mineralization in a metamorphic-meteoric fluid mixing zone, Westland, New Zealand: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 167-169. First author at Geology Dept., Univ. Otago, Dunedin, New Zealand.

See Fluid Inclusion Research, v. 21, p. 83. (E.R.)

CRISS, R.E. and FLECK, R.J., 1989, $\delta^{18}O$ map of the giant metamorphic-hydrothermal system around the Northern Idaho Batholith (abst.): Eos, v. 70, p. 1379.

CROCETTI, C.A. and HOLLAND, H.D., 1989, Sulfur-lead isotope systematics and the composition of fluid inclusions in galena from the Viburnum Trend, Missouri: Econ. Geol., v. 84, p. 2196-2216. First author at Goldberg, Zoino and Associates, Inc., 380 Harvey Road, Manchester, NH 03103.

Analyses of fluid inclusion leachates indicate that the composition of the ore-forming fluids of the Viburnum Trend was similar to that of typical oil-field brines. Relatively elevated K^+/Na^+ values (0.034-0.15, by weight) of the ore-forming fluids may reflect interaction of the fluids with granitic basement or with arkosic sediments. Br^-/Cl^- values (0.0042-0.0051, by weight) of the fluid inclusions in octahedral galena crystals are greater than that of present-day seawater (0.0035) and suggest that the brines from which the octahedral galenas were deposited originated as evaporated seawater. Br^-/Cl^- values (0.00125-0.0022) of the fluids from which the cubic galenas were deposited are significantly lower than that of present-day seawater, suggesting that much of the salinity of these fluids was derived from the dissolution of halite. $^{87}Sr/^{86}Sr$ ratios of 0.7097 to 0.7102 were determined for fluid inclusion leachates from a sample of cubic galena.

A rough correlation between the isotopic composition of Pb and S persists in galenas throughout the Viburnum Trend. The general trend of the isotopic data can be explained in terms of the mixing of two end members, one containing isotopically heavy S and less radiogenic Pb, the other containing isotopically light S and more radiogenic Pb. The isotopic composition of Pb and S in octahedral galenas is closer to that of the first end member; the isotopic composition of Pb and S in cubic galenas is closer to that of the second end member. The isotopic composition of the less radiogenic (normal) Pb component is similar to that of Pb in oil-field brines. The more radiogenic lead component has a composition that is consistent with a source of 1.0 to 1.2 Ga in age. The origin of the S in both end members appears to have been marine sulfate.

The results of various age determinations on the ores, the physical attributes required of the source basin, and the similarity between the composition of the ore-forming fluids and present-day Arkoma basin brines suggest that the Arkoma-Ouachita basin was the source of the ore-forming fluids during the later Carboniferous or the Early Permian. Correlation of the isotopic composition of Pb and S in the galenas strongly suggests that these elements were transported together in solution. Available geologic and geochemical data appear to be most consonant with the sulfate reduction model for ore deposition. (Authors' abstract)

CROSSEY, L.J., 1989, Aqueous thermal degradation of oxalate (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A49.

CUITINO, Lucia, DIAZ, Sergio and PUIG, Alaro, 1988, Aspects of mineralogy, geochemistry, and geothermometry in the hydrothermal deposits of Guanaco and Cachinal de la Sierra. Antofagasta, Chile (abst): Communicaciones, Una Revista de Geologia Andina (Communications, a Review of Andean Geology), 5th Geological Congress of Chile, Spec. Issue No. 39, p. 51 (in Spanish, translated by G. Landis).

The Guanaco (Au and Cu) and Cachinal de la Sierra epithermal deposits (Ag), situated in southern Antofagasta, are emplaced in a volcanic sequence comprised principally of ignimbrites along the margin of one of the volcanic calderas of a preserved system, developed during the lower Paleocene-Eocene period.

These vein-form deposits host a mineralogic association characterized at Guanaco by alunite, chalcedonic quartz, barite, hematite, kaolinite, dickite, pyrite, enargite, luzonite, and native Au, and at Cachinal de la Sierra by quartz (amethyst), sericite, adularia, fluorite, hematite, argentiferous galena, sphalerite, and Ag sulfosalts (polybasite-pearcite, stromeyerite, freibergite, proustite).

Lithogeochemical analyses (Au, Ag, Cu, Pb, Zn, As, Ba, Sb, Hg) indicate for Guanaco a strong relation [correlation] between As anomalies and mineralized bodies. At Cachinal, mineralization is associated only with Ag anomalies.

Fluid inclusion studies of vein quartz from these deposits indicate Th of Cachinal de la Sierra vary between 180° and 320°C, and of Guanaco between 150° and 180°C. Salinity values of the fluids, on both cases, are <5 eq. wt % NaCl (3% at Guanaco and 1% at Cachinal). Based upon calculations, the veins at Guanaco were formed ~50 m below the paleophreatic level, and ~100 m below at Cachinal. Other researchers have corroborated these results by fractionation of O isotopes in quartz from two veins at Cachinal de la Sierra, which indicate the [same] T as determined here, and the presence of meteoric water.

The mineralogy, paleotemperatures, and depth of formation determined for these deposits, as well as their position at the margin of the caldera, classify the Guanaco [deposit] as an acid-sulfate type epithermal deposit, and Cachinal de la Sierra as a sericite-adularia epithermal deposit. (Authors' abstract)

DAI, R.R., 1989, Granite-type rock bodies features and its minerogenesis of gold deposits in Tungling District, Anhui Province of China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-360-361. Author at Hefei Univ. of Technology, Hefei, P.R.C.

The rock mainly contains plagioclase, alkali feldspar, sphene, apatite, and so on. Inclusions are mostly gas-liquid. The T of the inclusions with the method of uniform take from the rock bodies was 1280°C-1150°C; the T of the P inclusions was 225°C-450°C. (From authors' abstract by E.R.) [sic; see p. 1]

DAMMAN, A.H., 1989, Hydrothermal orthoamphibole-bearing assemblages from the Gasborn area, West Bergslagen, central Sweden: Am. Mineral., v. 74, p. 573-585. Author at Inst. Earth Sci., Free Univ., de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

In the Gasborn area, West Bergslagen, central Sweden, two mineral assemblages are found in conduit zones for hydrothermal fluids from which manganiferous iron ores were deposited: (1) an older assemblage consisting of quartz, albite, phengite, chlorite, and Zn- and Mn-bearing magnetite and (2) a younger, overprinting assemblage, consisting of biotite, cordierite, orthoamphiboles, cummingtonite, Zn- and Mn-free magnetite, hercynite, and corundum.

The relative fugacity of HF ($f'_{HF} = f_{HF}/f_{H2O}$) varies between veins from $10^{-3.53}$ to $10^{-4.58}$ and the relative fugacity of HCl (f'_{HCl}, i.e., f_{HCl}/f_{H2O}) varies from $10^{-1.68}$ to $10^{-2.60}$. In and along each hydrothermal vein, f'_{HF} is relatively constant, and the amount of F incorporated in coexisting orthoamphibole and biotite is controlled by their respective Mg and Fe contents. In and along each vein, f'_{HCl} decreases when going from the vein outward, and X_{Mg}[= Mg/(Mg + Fe^{2+})] values of coexisting orthoamphibole and biotite show a negative correlation with their respective Cl contents, suggesting that along each vein, variations in f'_{HCl} and X_{Mg} mutually influence one another.

The Mg and Fe contents of orthoamphibole and biotite appear to be controlled by the differences in f'_{HF} and f'_{HCl} between veins. Ba and Ti are preferentially incorporated into biotite and show a positive correlation with Cl. Mn is preferentially incorporated into the orthoamphiboles, but does not show a correlation with either Cl or F. (From authors' abstract by E.R.)

DAVIS, D.W., LOWENSTEIN, T.K. and **SPENCER, R.J.**, 1989, Melting behavior of fluid inclusions in laboratory-growth halite crystals in the systems NaCl-H_2O, NaCl-KCl-H_2O, NaCl-$MgCl_2$-H_2O, and NaCl-$CaCl_2$-H_2O (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 19. First author at Dept. Geol. Sci., S.U.N.Y., Binghamton, NY 13901.

FI in laboratory-grown halite crystals in the systems NaCl-H_2O, NaCl-KCl-H_2O, NaCl-$MgCl_2$-H_2O, and NaCl-$CaCl_2$-H_2O were studied to document their melting behavior. There are significant differences between observed melting behaviors and published equilibrium relations in these systems.

The observed T of first melting (Te) often do not match the predicted values. In the NaCl-H_2O and NaCl-KCl-H_2O systems, observed Te are up to 15°C below the equilibrium eutectic T due to the formation of metastable mineral assemblages. Inclusion fluids in these systems fail to form hydrohalite during freezing; ice and metastable halite form instead. During warming, ice and metastable halite begin reacting in each system at T as low as -35°C and -40°C, respectively. A second metastable phase ($MgCl_2$*nH_2O or $CaCl_2$*nH_2O) may form in the NaCl-$MgCl_2$-H_2O or the NaCl-$CaCl_2$-H_2O systems. In inclusions which form such metastable hydrates, Te may be as low as -70°C. Inclusions which form the predicted stable hydrate ($MgCl_2$*12H_2O or $CaCl_2$*6H_2) have Te which match the predicted Te to within 3°C.

For all systems studied, the observed Tm hydrohalite is reproducible to within ±0.1°C. [This] may be used to accurately fix the chemical composition of the inclusion fluid.

Tm ice in the presence of hydrohalite in the systems NaCl-H_2O and NaCl-KCl-H_2O is reproducible and closely matches the predicted T. In the NaCl-$MgCl_2$-H_2O and the NaCl-$CaCl_2$-H_2O systems, Tm ice in the presence of hydrohalite occur at lower T than predicted, and may vary more than 15°C in inclusions with identical bulk compositions. However, the Tm ice in inclusions with no hydrohalite is reproducible to within ±0.1°C and can also fix the chemical composition of the fluid.

The limit of detection of sylvite dxls (KCl) in the NaCl-KCl-H_2O system is ~5 wt % KCl; Tm sylvite matches the published equilibrium data to within 3°C and can fix the K^+ molality.

The formation of metastable phases may cause misinterpretation of FI data in natural samples. This is especially true for inclusions with Te below -37°C which may be erroneously interpreted as being rich in Ca^{++}. A procedure for analyzing natural inclusions is proposed based on the behavior of the synthetic inclusions produced in this study. (Authors' abstract)

DAWSON, J.B., PINKERTON, H. and **PILE, D.M.**, 1989, 1988 Activity of the active carbonatite volcano, Oldoinyo Lengai - Uniquely low lava temperatures and viscosities (abst.): Eos, v. 70, p. 497-498.

DE ALVARENGA, C.J.S., CATHELINEAU, M., DUBESSY, J. and **TROMPETTE, R.**, 1989, Microfracturing and associated N_2-CH_4 or CO_2-rich fluids in barren and Au-bearing quartz veins from Cuiaba, Brazil (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 23. First author at Lab. G*ol. Dynam. & Petrol. de la Surface, Centre de St. Jerome, 13397, Marseille, France.

The upper Proterozoic Cuiaba Group of Mato Grosso, Brazil, is composed of low-grade clastic metasediments. Three generations of quartz veins are associated with the structural evolution of this area. (...) A statistical study of microstructural markers (oriented FI trails, opened microcracks) was carried out on quartz veins from three localities. One of them is characterized by significant Au extraction. Most quartz veins show three main preferred orientations, N0-25E, N30-60E, and N120-150E. Microthermometric studies and Raman spectrometry allow four different types of fluids to be distinguished which occur in specific FI trails.

(i) N_2-CH_4-rich fluids with minor amounts of CO_2, H_2S, and C, with Th ranging from -126 to -115°C.

(ii) CO_2-rich fluids with CH_4 and N_2, and a variable H_2O amount. Tm CO_2 range between -59 and -57°C. Salinity is in the range 8.5-11.1 wt % NaCl eq. and Th ranging from 240 to 300°C.

(iii) CO_2-rich fluids with N_2 and variable amounts of H_2O. Tm CO_2 range between -59 and -57°C, salinities and Th vary between 8.5-11.1 wt % NaCl eq. and 240-300°C.

(iv) H_2O-NaCl-rich fluids having a variable salinity (1.5 to 10.5 wt % NaCl eq.) and Th.

Most fluids can be observed over [the] same region within the three generations of quartz veins, indicating an important fluid circulation associated with the last phase of brittle deformation. However, the Au mineralized zone is characterized by the presence of CO_2-N_2-rich fluids with specific features. FI are oriented along several well defined directions, as for instance the preferred orientation N120-150E for the N_2-CH_4-rich fluids. Thus, the study shows the importance of coupled studies of microstructural markers together with FI studies for understanding the geometry and chronology of the fluid circulation. (From authors' abstract by E.R.)

DE MAESSCHALCK, A.A. and **OEN, I.S.**, 1989, Fluid and mineral inclusions in corundum from gem gravels in Sri Lanka: Mineral. Mag., v. 53, p. 539-545. Authors at Inst. Earth Sciences, Free Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

Mineral and FI were studied in seven gem corundums from gravels of three areas in Sri Lanka. All FI are pure CO_2. Microthermometry results on P FI suggest formation of corundum under granulite facies metamorphism (>630°C, 5.5 kbar). S FI indicate different retrograde events of post-metamorphic cooling and uplift for different source areas. (Authors' abstract)

DE VIVO, B., BELKIN, H.E., BARBIERI, M., CHELINI, W., LATTANZI, P., LIMA, A. and **TOLOMEO, L.**, 1989, The Campi Flegrei (Italy) geothermal system: A fluid inclusion study of the Mofete and San Vito fields: J. Volcanol. Geotherm. Res., v. 36, p. 303-326. First author at Dipartimento di Geofisica e Volcanologia, Largo S. Marcellino 10, 80138 Napoli, Italy.

A fluid inclusion study of core from the Mofete 1, Mofete 2, Mofete 5, San Vito 1, and San Vito 3 geothermal wells (Campi Flegrei, Campania, Italy) indicates that the hydrothermal minerals were precipitated from aqueous fluids ($\pm CO_2$) that were moderately saline (3-4 wt % NaCl eq.) to hypersaline (>26 wt % NaCl eq.) and at least in part, boiling. Three types of P fluid inclusions were found in authigenic K-feldspar, quartz, calcite, and epidote: (A) two-phase [liquid (L) + vapor (V)], liquid-rich inclusions with a range of salinity; (B) two-phase (L + V), vapor-rich inclusions with low salinity; and (C) three-phase [L + V + crystals (NaCl)], liquid-rich inclusions with hypersalinity. Results of microthermometric and crushing studies are reported for 20 drill core samples taken from the lower portions of the five vertical wells.

Data presented for selected core samples reveal a general decrease in porosity and increase in bulk density with increasing depth and T. Hydrothermal minerals commonly fill fractures and pore-spaces and define a zonation pattern, similar in all five wells studied, in response to increasing depth (P) and T. A greenschist facies assemblage, defined by albite + actinolite, gives way to an amphibolite facies, defined by plagioclase (andesine) + hornblende, in the San Vito 1 well at ~380°C. the fluid inclusion salinity values mimic the saline and hypersaline fluids found by drilling. Fluid inclusions V/L Th increase with depth and generally correspond to the extrapolated down-hole T. However, fluid inclusion data for Mofete 5 and mineral assemblage data for San Vito 3, indicate fossil, higher-T regimes.

A limited $^{87}Sr/^{86}Sr$ study of leachate (carbonate) and the leached cores shows that for most samples (except San Vito 3) the carbonate deposition has been from slightly ^{87}Sr-enriched fluids and that Sr isotopic exchange has been incomplete. However, San Vito 3 cores show an approach to fluid/rock Sr equilibrium with a fluid similar to modern ocean water in $^{87}Sr/^{86}Sr$ ratio.

The Campi Flegrei volcanic system has evolved undersaturated products, mostly trachyte, and defines a large (~12 km) caldera. The hydrothermal system developed in this location can be used as an analog for fossil systems in similar trachytic environments. The potential for ore mineralization is expressed by the recognition, from fluid inclusions and drilling data, of ore-forming environments such as boiling and brine stratification. (Authors' abstract)

DE VIVO, Benedetto, FREZZOTTI, M.L. and **CLOCCHIATTI, Robert**, 1989, Fluid and melt inclusions in ultramafic nodules and phenocrysts from the alkaline lavas of Etna [volcano]: Bollettino GNV, v. 1989-2, p. 827-833 (in Italian, English abstract).

Fluid and melt inclusions have been analyzed in clinopyroxene and olivine crystals of 14 nodules (mainly dunites and werhlites) and phenocrysts from the alkaline lavas of "Antichi Centri Alcalini" of M. Etna. Microthermometric analyses, coupled with Raman and microprobe investigations, have allowed us to identify two major FI types: (1) Melt inclusions ($\pm CO_2$ of very low density). In these inclusions a residual melt is present together with kaersutite, magnetite and Cl-apatite daughter crystals. Residual glass has a trachitic composition. Cl content is between 3200 and 6800 ppm. (2) Mixed "CO_2 + glass" inclusions. 128 Th measurements (both to liquid and vapor, ThL and ThV) indicate densities of 0.23-0.76 g/cm^3 with a bimodal distribution between 0.23-0.39 g/cm^3 and 0.45-076 g/cm^3.

It is concluded that CO_2 was present as an immiscible fluid phase at P of at least 4.3 kbar. The distribution of density values suggests a continuous interaction between nodules and ascending magma with a maximum ~3.5 kbar. The volatile evolution is discussed. (H.E.B.)

DE VIVO, B., LIMA, A. and **SCRIBANO, V.,** 1989, CO_2 fluid inclusion geobarometry of upper mantle ultramafic nodules from Hyblean Plateau, southeastern Sicily, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 24. First author at Dipart. di Geofisica e Vulcanol., Largo S. Marcellino 10, 80138 Napoli, Italy.

The Hyblean Plateau (southeastern Sicily, Italy) consists of a thick Meso-Cenozoic carbonate sequence with interbedded volcanic horizons. Alkaline and tholeiitic basalts form the dominant volcanic lithotypes. The alkaline basalts contain ultramafic and mafic xenoliths, the study of which has already provided some insight into the nature of the Hyblean lower lithosphere. The ultramafic nodules consist of peridotites and pyroxenites. The former are spinel-bearing harzburgites, with porphyroclastic to protogranular texture. Pyroxenites consist of several types of websterites, which may be split into two main groups: Cr-diopside-bearing and Al-augite-bearing. Coarse polygonal texture dominates most of the above mentioned websterites, except for a few, exhibiting well developed foliation. The ultramafic nodules have been interpreted as fragments of Hyblean upper mantle: websterites probably derive from recrystallization of magmatic liquid intruded as dikes or pods into the peridotites. The mineral chemistry of the nodules indicates T between 800 and 1150°C.

FI containing CO_2 and sometimes various proportions of silicate glass have been measured in olivine, orthopyroxene and clinopyroxene. The inclusions amenable to measurements are all S; they occur as trails of tiny, ovoid and spherical, very rich CO_2 inclusions, often crosscutting the deformation lamellae. The CO_2 fluids exsolved and migrated along discontinuities of the crystalline structures and intragranular fracturing due to thermal stresses or P release during the xenolith ascent to the surface. The Th of vapor (V 1%) and liquid (L 99%) ranges from -43 to 20.5°C, yielding a CO_2 density from 0.20 to 1.12 g/cm^3. The frozen inclusions melt in a very narrow range with Tm from -55.3 to -57.6°C, suggesting essentially pure CO_2. Assuming an indicative Tt at 1050°C for a pure CO_2 system, the measured inclusions have been trapped between 580 and 10925 bars (with major P clusters between 7375 and 10925 bars), which correspond to depths of 2 km to 41 km, with an average rock/magma density of 2.7 g/cm^3. (Authors' abstract)

DE VIVO, B. and **SASADA, Masakatsu,** 1989, Fluid inclusions from SN-7D drill hole, Sengan geothermal area: Geothermal Research Society of Japan Meeting, Abstracts (in Japanese, translated by Y. Seki). First author at Univ. Naples.

Fluid inclusions were studied from SN-7D (depth = 2484 m) drilled in the Sumikawa geothermal field, Sengan area, Akita, Japan. Four samples from <1921 m have vein minerals consisting of wairakite, calcite and anhydrite. Two samples from greater depth are quartz phenocrysts in tonalite. Th and salinity from melting point of fluid inclusions in wairakite and some calcite are concordant with T and salinity of the present geothermal fluid. On the other hand, two types of fluid inclusions are recognized in tonalite. One is a group with high salinity and a wide range of Th, and the other with low salinity and a narrow range of Th. The latter is considered to be produced during present geothermal activity. Th is summarized in the table. (Authors' abstract)

Depth	Sample	Range of Th	Th peaks (descend. order)	Remarks
1045 m	vein	265-285°C		
1435	vein	290-310	300°C	
1505	vein	220-335	280	
1921	vein	285-320	305	
2292	tonalite	235-375	315, 350, 250	

2484	tonalite	300-330	320	low salinity only
		240-300	280	
		280-290	285	low salinity only

DEINES, Peter, 1989, Regularities in the C and nitrogen content of the mantle revealed through studies of diamonds and the chemistry of their inclusions (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 18-20.

DEINES, Peter, HARRIS, J.W., SPEAR, P.M. and **GURNEY, J.J.,** 1989, Nitrogen and ^{13}C content of Finsch and Premier diamonds and their implications: Geochim. Cosmochim. Acta, v. 53, p. 1343-1355. First author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802, USA.

The N content and state of aggregation have been determined spectroscopically for diamonds from the Finsch (93) and the Premier (116) kimberlite, South Africa. The ranges of concentration for diamonds with eclogitic (E-Type) and peridotitic (P-Type) mineral inclusions are: Finsch: E-Type, 29 to 1639 ppm, P-Type, 7 to 1206 ppm; Premier: E-Type, 15 to 1359 ppm, P-Type, 7 to 1086 ppm. In both kimberlites N-free diamonds (Type II) contain less frequently eclogitic inclusions. Among E-Type diamonds there are none of Type II in the Finsch and 1% in the Premier sample suite; for P-Type diamonds the respective percentages are 29 and 25%. There is no significant difference in the N aggregation state between E-Type and P-Type diamonds within each kimberlite; however, there is a significant difference between the two locations. The N in the B form amounts to 26 $\pm$ 29% (n = 65) in Finsch and to 48 $\pm$ 26% (n = 101) in Premier diamonds. No correlation between $\delta^{13}C$ and N content or aggregation state is observed. However, within the eclogitic and peridotitic paragenesis, groups of diamonds of very similar N concentration, $\delta^{13}C$, and mineral inclusion composition can be recognized. One of these may be common to both kimberlites. Some of the diamonds in the two kimberlites may have had a common origin but subsequent thermal histories, which differed for the sample suites from the two diatremes. The N content of the diamonds is a function of local N concentration, T and oxygen fugacity. The dependence on the last of these can cause complex relationships between $\delta^{15}N$, $\delta^{13}C$ and N content of diamonds. (Authors' abstract)

DELITSYNA, L.V., DELITSYN, L.M., PAVLOV, E.G., KOLESNIKOV, V.M. and **TOV, G.M.,** 1989, Immiscibility of liquid phases in the system $Ca_5(PO_4)_3F$-SiO_2-NaF-CaO-MgO and its significance in the genesis of apatite ores: Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 162-166 (in Russian; see Translations).

DELOULE, Etienne and **TURCOTTE, D.L.,** 1989, The flow of hot brines in cracks and the formation of ore deposits: Econ. Geol., v. 84, p. 2217-2225. First author at Laboratoire de Géochemie et Cosmochimie, Institut de Physique du Globe, 4 place Jussieu, 75252 Paris Cedex 05, France.

We examined the thermal evolution of solutions transported vertically by turbulent flow in fractures and its implications for Mississippi Valley-type ore deposition. The main parameter governing the flow is fracture width, which determines the flow rate, volume, and thermal evolution of the transported fluid. We assumed local equilibrium and traced the chemical evolution of the transported solutions, the mineral deposits associated with the cooling of these solutions, and the limits of fracture clogging. The volume of fluid expelled and the fracture width determine the location of the deposit and, hence, the deposit type, i.e., carbonate hosted or vein. We show that a network of thin cracks can indeed transport the volume of brines needed for the genesis of large Mississippi Valley-type ore deposits, such as the Southeast Missouri Pb district. (Authors' abstract)

DES MARAIS, D.J., 1989a, Thermal CO_2 outgassing: Source signatures, sizes and significance (abst.): Eos, v. 70, p. 1377.

DES MARAIS, D.J., 1989b, Reply [to B. Marty re mantle carbon flux calculations]: Eos, v. 70, no. 1, p. 1 and 3.

A reply to Marty, 1989, this volume. (E.R.)

DEVRIES, Suzanne, HANSEN, Edward, RADHAHRISHNA, T. and **MATTHI, John**, 1989, Fluid inclusions in cordierites from Kerala, south India (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 20. First author at Dept. Geol. and Geophys. Sci., Princeton Univ.

Although the compositions of both cordierite and FI have been used to estimate compositions of metamorphic fluids, rarely have they been reported together. We have found CO_2-rich FI within cordierites from an orthopyroxene-bearing gneiss collected in the high-grade Khondalite belt of southern Kerala. These inclusions occur in trails and are rectangular with the same point group symmetry (2/m 2/m 2/m) as the cordierites themselves. Tm are between -56.5° and -57.7° indicating that the inclusions are predominantly CO_2 but may contain small amounts of other components. The 2Vx of the cordierites range between 95° and 104°. These values suggest the presence of CO_2 in the structural channels of the cordierites. This has been confirmed by a qualitative analyses of the infrared spectra of the cordierites done by Dr. Charles Geiger of the Technische Universitat Berlin. Both H_2O and CO_2 were detected with CO_2 predominating. This indicates equilibration with a CO_2-rich fluid and hence, the compositions of the FI and cordierites are roughly consistent with each other. The FI with Th L-V(L) all have Th >25°C and many of the inclusions have Th L-V(V). The densities of all these inclusions are much too low to represent unmodified samples of a fluid trapped under the metamorphic conditions (T = 700°-800°C, P = 5 Kb) indicated by solid mineral geothermometers and geobarometers.

FI also occur in planar arrays within the quartz, plagioclase, alkali feldspar and garnet from the gneiss. Tm of these range between -56.4 and -57.9°C, while Th is between 5°C and 30°C. Thus they appear to have compositions similar to the inclusions in the cordierite but generally have higher densities (although still too low to represent unmodified samples of the metamorphic fluid). Some planar arrays within quartz are made up of FI shaped as irregular branching tubes and these have relatively high Th. Other arrays are made up of inclusions with hexagonal, negative crystal shapes and relatively low Th. Many other trails have inclusions which fall between these two extremes. Under the assumption that these different shapes represent different stages in the annealing of a healed fracture, these relationships suggest that the inclusions were trapped over a period of time along a segment of the post-metamorphic uplift path which crossed the isochores from high to low density. Thus there must have been a source of fluids, capable of yielding CO_2-rich inclusions, operating over an extended period of time during the post metamorphic history. The very low densities in the cordierite FI probably represent a decrease in density after trapping, perhaps through exchanges with the volatiles in the structural channels. (Authors' abstract)

DEVYATYKH, G.G., SENNIKOV, P.G., TOKHADZE, K.G. and **SHKRUNIN, V.Ye.**, 1989, Vibrational spectra of liquid hydrogen sulfide and hydrogen selenide: Doklady Akad. Nauk SSSR, v. 309, no. 3, p. 638-640 (in Russian).

IR absorption spectra at 200-295 K within the range 6000-1000 cm^{-1} of gas and liquid H_2S and H_2Se are presented; pertinent to the IR studies of the fluid inclusion fillings. (A.K.)

DIAMOND, Larryn, 1989a, Hydrothermal geochemistry of late-metamorphic gold-quartz veins at Brusson, Val d'Ayas, Pennine Alps, NW Italy: 1986, Thesis at Institut für Mineralogie und Petrographie, ETH Zürich; abstract in Schweiz. Mineral. Petrog. Gesellsch., 1989, Information Bull., no. 6.

This thesis investigates the physicochemical controls on ore deposition in a swarm of Au-bearing hydrothermal quartz veins at Brusson, Val d'Ayas, NW Italy. The Brusson locality belongs to the Monte Rosa Gold District, an extensive province of epigenetic mineralization in the Western Alps.

The steeply-dipping veins at Brusson discordantly traverse folded polymetamorphic gneisses of the Penninic Monte Rosa Nappe and the overlying Piemonte Ophiolite Nappe. K-Ar radiometric analyses of hydrothermal muscovites yield formation ages of around 32 Ma. Reconstruction of the P-T evolution of the Brusson area assigns vein formation to a period of rapid uplift and cooling, some 4-8 Ma after the local peak of Meso-Alpine greenschist-facies metamorphism. Ore-bearing fluids initially ascended to the level of Brusson along active extensional faults, but later veining proceeded via repeated episodes of hydrofracturing.

The main stage of vein mineralization comprises quartz + dolomite + muscovite + rutile + pyrite + chalcopyrite + Au. This paragenesis grades laterally into the wallrock metamorphic assemblages through narrow, zoned, metasomatic haloes. Wallrock alteration around individual veins is continuously traceable in metagranitic, pelitic, metabasite, carbonate and serpentinite wallrocks. Au distribution correlates strongly with wallrock lithology: free Au is restricted to vein sections enclosed by highly altered metagranites and pelites, whereas Au as inclusions in pyrite also is associated with metabasites. A final stage of mineralization comprises calcite + galena + tetrahedrite, and is characterized by local replacement of the main-stage paragenesis.

Fluid inclusion studies are based on new adaptions of standard methods. A procedure has been devised to calculate the P-T stability of CO_2-hydrate (clathrate) in inclusions that contain CH_4 and N_2. The calculations, incorporating microthermometric, phase-equilibrium and Raman-microprobe data, afford precise determination of bulk fluid salinity in samples where carbonic-phase homogenization occurs at higher T than clathrate dissociation. For inclusions exhibiting total homogenization to the liquid state, phase relations in the CO_2-H_2O-NaCl system permit bulk composition to be obtained accurately by iterative computation, avoiding reliance on optical estimates of relative phase volumes. Reinterpretation of petrographic and phase-equilibrium criteria enables the occurrence of syn-depositional fluid mixing or unmixing to be recognized from fluid inclusion data.

Fluid inclusions found in vein quartz have been analyzed by petrographic, microthermometric, Raman-microprobe, crush-leach and phase-petrologic techniques. A computational algorithm has been constructed to derive bulk fluid composition and density from the collected data. The main-stage Au-bearing fluid at Brusson was complex (mole % H_2O = 94-95, CO_2 = 6-5, N_2 = 0.2, CH_4 = 0.003, Cl = 1.55, Na = 1.4, K = 0.07, Ca = 0.02, Mg = 0.002, S = 0.02), but its composition varied little with time. Later populations of high-XCO_2 and low-XCO_2 fluid inclusions show that the originally homogeneous main-stage fluid unmixed (boiled) at the onset of final-stage (Au-free) mineralization.

Thermodynamic calculation of the stability of vein- and alteration-mineral assemblages limits main-stage mineralization to conditions below 300°C and 1200 bars. The minimum trapping conditions of P fluid inclusions set a lower bracket on early mineralization at 260-270°C and 700-750 bars. Au deposited intermittently as the main-stage fluid progressively cooled and decompressed, until retrograde boiling commenced at around 230°C and 550 bars.

Evaluation of the kinetic controls on C-O-H equilibria allows the analyses of fluid inclusions to be used in calculating fO_2 of the main-stage hydrothermal fluid. The result, in agreement with petrographic evidence, indicates that the hydrothermal fluid was in equilibrium with wallrock graphite during Au transport and deposition.

Fluid inclusion analyses coupled with interpretations of wallrock alteration reactions point to a reduced sulphur complex as the dominant species of Au transport. Au deposition occurred apparently in response to wallrock-buffered fluctuations in fluid pH, and to the bulk extraction of dissolved sulphur attending wallrock pyritization. Other precipitation mechanisms are demonstrably less significant. In addition to placing tight constraints on the possible origins of the Au-bearing solutions, this study shows that Au localization at Brusson is a predictable consequence of the chemical interaction between the hydrothermal vein fluid and its adjacent wallrocks. (Author's abstract)

DIAMOND, L.W., 1989b, Fluid inclusion compositions in Archaean shear-hosted gold-quartz veins of the Rice Lake-Bissett district, Uchi subdistrict, N.E. Manitoba: Consequences for ore genesis and exploration (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-119. Author at Dept. Earth Sci., Carleton Univ., Ottawa, Ontario K1S 5B6, Canada.

The shear-hosted Au-quartz veins in the Rice Lake-Bissett district are typical of Archaean mesothermal deposits elsewhere in the Superior Province, both with respect to vein- and wall-rock alteration mineralogy, and structural setting. At present, however, Rice Lake-Bissett is only a marginally productive Au district. FI studies have been carried out on auriferous and barren quartz veins in order to examine any controls on ore grade reflected by fluid composition. A variety of petrographic, microthermometric, and Raman spectroscopic investigations have revealed distinct generations of hydrothermal fluid within the veins, of differing compositions and densities. Au-bearing solutions contain 4-9 mol % CO_2, 1.5 mol % eq. NaCl and very small amounts of CH_4, N_2 and H_2S. Regionally abundant post-ore aqueous inclusions contain 6 mol % eq. NaCl, no CO_2 but detectable CH_4. Most veins appear to have formed under relatively reducing conditions between 230 and 340°C. The FI data constrain the possible mechanisms of Au deposition in several veins, in particular the San Antonio mine. Together with the results of crushing-stage tests that delineate the spatial distribution of high-P CO_2-bearing FI in the wall rocks of the deposits, this study has practical significance for the design of exploration strategies in the Rice Lake-Bissett district. (Author's abstract)

DIAMOND, L.W., MARSHALL, D.D., JACKMAN, J.A. and **SKIPPEN, G.B.**, 1989a, Elemental analysis of individual fluid inclusions in minerals by secondary-ion mass spectrometry (SIMS) (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 21. First author at Dept. Earth Sci., Carleton Univ., Ottawa, Canada.

A technique is being developed to quantitatively analyze element concentrations in individual FI by secondary ion mass spectrometry (SIMS), using a CAMECA-4F ion microprobe. SIMS analysis has the potential to detect *all* elements, their isotopes and polyatomic clusters between masses 1 and 500. While little information can be gained about element speciation within FI, SIMS has the unique capacity to determine even the lightest of elements with a sensitivity on the order of ppm.

The analytical method, first attempted by Nambu et al. (1977, Mining Geol. (Japan), 27, 40) is destructive: FI are opened in the vacuum chamber of the microprobe by drilling through the walls of the host crystal with a 10-20 KeV beam of charged P ions (either O+, O-, Ar+ or Cs+). The crater sputtered by the P beam is ~50 μm in diameter, thus permitting precise and individual opening of preselected FI. A variety of S ions are emitted from the FI in response to the impact of the P beam. Fractions of these S ions are analyzed in a mass spectrometer and their time-integrated intensities are proportional to the concentration of parent elements in the target inclusions. Up to 14 distinct masses of S ions may be analyzed simultaneously.

Calibration of the method of quantitative analysis is undertaken using FI standards that have been synthesized with a wide range of compositions, including mixed gases and electrolytes. (Authors' abstract)

DIAMOND, L.W., MARSHALL, D.D., JACKMAN, J.A. and **SKIPPEN, G.B.**, 1989b, Elemental analysis of individual fluid inclusions in minerals by secondary-ion mass spectrometry (SIMS) (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-94. First author at Dept. Earth Sci., Carleton Univ., Ottawa, Ontario K1S 5B6, Canada.

A SIMS technique is being developed to quantitatively analyze element concentrations in individual FI, using a CAMECA-4F Ion Microprobe. SIMS has the potential to detect *all* elements, their isotopes and polyatomic clusters up to mass 500, with a sensitivity on the order of ppm. The method is destructive: pre-selected FI are opened under vacuum by sputtering through the walls of the host crystal with an ion beam (either O^+, O^- or Cs^+). Excellent spatial control permits individual inclusions to be opened without interfering with adjacent inclusions. Secondary ions emitted upon opening the inclusions are analyzed in a mass spectrometer, their time-integrated intensities being proportional to the concentration of parent elements in the target inclusion. Calibration of the method for quantitative analysis is undertaken using FI standards that have been synthesized with a wide range of compositions, including mixed gases and electrolytes. Inclusions as small as 3 micrometers diameter and as dilute as 2 wt % salt yield semiquantitative element ratios. Analyses of FI from Archaean Au-quartz veins illustrate the application of the SIMS method. (Authors' abstract)

DICKINSON, T. and **JONES, J.H.**, 1989a, Ba and Th partitioning between immiscible silicate melts: Further evaluation of the role of silicate liquid immiscibility in the petrogenesis of lunar granites (abst.): 52nd Annual Meeting of the Meteoritical Society, Vienna Austria, July 31-August 4, 1989, Abstracts and Program, LPI Contribution 712, p. 45. Authors at NASA Johnson Space Center, Houston, TX 77058.

DICKINSON, T. and **JONES, J.H.**, 1989b, The role of silicate liquid immiscibility in the petrogenesis of lunar granites: New evidence from Ba and Th partitioning experiments (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A370.

DIEDEL, R., REDECKE, P. and **FRIEDRICH, G.,** 1989, Lead-zinc mineralization of Zechstein carbonates of NE-German trough as a result of intraformation replacement (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 32 (in German) (supplementary issue to European J. Mineral., v. 1.).

At the N margin of the Lower-Saxonian tectogen in main dolomite of the Stassfurt series Z2 there occur ore bodies up to 18 m thick, consisting of galena, sphalerite, pyrite, dolomite, anhydrite, and fluorite. The studied samples came from the depth of 3000 m of the borehole Barenburg 28. Fluid inclusions in sphalerite and anhydrite yielded Th 140-150°C, Tm -23°C, Te -77 to -83°C; the latter indicates presence of methane. The presence of hydrocarbons in carbon dioxide inclusions suggest the Upper Carboniferous beds as the solution source. (From the authors' abstract translated by A.K.)

DING, K. and **SEYFRIED, W.E., Jr.,** 1989, H_2 and H_2S concentrations as indicators of temperature in ridge crest hydrothermal systems (abst.): Eos, v. 70, p. 1397.

DINGWELL, D.B., 1989, Effect of fluorine on the viscosity of diopside liquid: Am. Mineral., v. 74, p. 333-338.

DINGWELL, D.B. and **WEBB, S.L.,** 1989, The temperature-dependence of water speciation in rhyolite melts: Analysis of quench-rate dependent speciation using relaxation theory (abst.): Eos, v. 70, p. 501.

DIXON, J.E., CLAGUE, D.A. and **STOLPER, E.M.,** 1989, Degassing history of H_2O, S, and CO_2 in submarine tholeiitic lavas from Kilauea Volcano, Hawaii (abst.): Eos, v. 70, p. 1422.

DIXON, P.R. and **RYE, D.M.,** 1989, Fluid mixing and the origin of large Zn ± Pb ± Ba deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A7.

DOBES, Petr and **ZAK, Karel,** 1989, Ag-Pb-Zn and U deposits of the Pribram ore district - Fluid inclusion and stable isotope study (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 4. Authors at Geol. Survey, Malostranske nam. 19, 118 21 Praha 1, CSSR.

The hydrothermal vein deposits of Variscan age in the Pribram ore district, i.e., the polymetallic deposits Brezove Hory, Vrancice, Bohutin and the U deposit, are situated about 60 km SW of Prague, around the town Pribram.

Vrancice deposit is situated in rocks of the Central Bohemian Pluton and is represented by higher Ag content and presence of Cu and Zn ore similar to that of the Pribram deposit. Other polymetallic deposits (Brezove Hory, Bohutin) occur along the marked "Clay Fault" that separates the Cambrian clastic formation from the Proterozoic series. Ore veins are feather structures associated with the Clay Fault. They accompany diabase dikes and form similar structural pattern. The main concentrations of ore veins is in the Cambrian syncline. There are many mineral generations and thus mineralization is classified as polyascendent.

The U deposit occurs within 25 km long belt which is bound to the exocontact of the pluton and is controlled by two faults. Veins cut metamorphosed series of the Proterozoic sediments. The oldest mineralization is similar to Ag-Pb-Zn type, younger stages contain five generations of calcite and uraninite.

FI within vein minerals (quartz, sphalerite, siderite, barite, dolomite-ankerite carbonate, calcite) are dominated by a gas-liquid type without CO_2 or CH_4. Th from Brezove Hory deposit range from 235 to 120°C for higher levels (about -600 m) and from 270 to 150°C for deeper part of the deposit (-1200 m). Th of inclusions from Vrancice deposit are rather low—from 190 to 100°C. The total range of Th from all generations of calcites from the U deposit lies within the range 110-180°C. Required P corrections for Th are less than 5°C for Vrancice and about 10°C for Brezove Hory deposits.

FI salinities range from 10 to 25 wt % NaCl eq. for older mineralization stages and from 1 to 15 wt % NaCl eq. for younger calcites of the Vrancice and U deposits. NaCl, $CaCl_2$ and $MgCl_2$ are dominant salts of solutions.

Isotopic compositions of S, C and O was determined in hydrothermal sulphides, sulphates and carbonates, in sedimentary carbonates as well as in accessory sulphides of rocks.

It was possible to calculate crystallization T for siderite, dolomite-ankerite and calcite. By using $\delta^{13}C$ and $\delta^{18}O$ values of hydrothermal carbonates, T gradient of ~100°C/1500 m of the known vein depth at the Brezove Hory deposit was established. Similar T decrease was found at the U deposit.

According to C and S isotope studies, the source of hydrothermal fluids of the polymetallic stage is evidently below the Upper Paleozoic complexes, either within granitic rocks or in the lower crust, except for Brezove Hory deposit, where participation of the Upper Proterozoic source is probable. On the contrary, hydrothermal veins of the U deposit derived several of their components from the upper crust. (Authors' abstract)

DOBSON, P.F., EPSTEIN, Samuel and **STOLPER, E.M.**, 1989, Hydrogen isotope fractionation between coexisting vapor and silicate glasses and melts at low pressure: Geochim. Cosmochim. Acta, v. 53, p. 2723-2730. Authors at Division of Geological and Planetary Sciences, 170-25 California Institute of Technology, Pasadena, CA 91125.

A series of experiments was performed to determine the H isotope fractionation factors between water vapor and "water" dissolved as hydroxyl groups in rhyolitic and feldspathic glasses and melts. Experiments were carried out in quartz tubes with a large excess of water at 530-850°C and PH_2O = 1.4-2.8 bars. Infrared measurements of water concentration profiles and isotopic reversal experiments indicate that equilibrium was attained during the 210-5400 hr runs.

The fractionation factors ($[D/H_{vapor}]/[D/H_{glass}]$) between the vapor and dissolved water in the glasses decrease from about 1.051 to 1.040 for rhyolite glass and 1.049 to 1.035 for albite-orthoclase glass as T increases from 530 to 750°C. These fractionations are greater than those observed for most hydrous mineral-water systems at these T, perhaps reflecting the strong H bonding of hydroxyl groups in the studied glasses. The measured fractionation factor for rhyolite melt accounts for the observed decreases in δD with decreasing water contents of obsidians erupted from young rhyolitic volcanoes, and supports a two-stage degassing history of these magmas. The variation of δD values with water contents of explosively erupted obsidians can be explained by a closed-system vapor-melt partitioning, whereas the low water contents and δD values of the quiescently erupted domes are interpreted to be a result of open-system degassing. (Authors' abstract)

DODEN, A.G. and **NORDLIE, B.E.**, 1989, Evidence for high water pressure in net-veined granites of SE Iceland (abst.): Eos, v. 70, p. 498.

DOMINGO, B.B., SANTIAGO, A.B., FERNANDEZ, A.T. and **GOLLA, G.U.**, 1989, Geology and gold mineralization of Co'O mine, Bunawan, Agusan Del Sur, Philippines (abst.): Geocon '89, 2nd Annual Convention, Geol. Soc. Philippines, Abstracts (unpaginated). Authors at Banahaw Mining and Development Corp.

This paper attempts to describe and produce an exploration model based on the Co'O Au and Ag deposit.

Andesitic volcaniclastics is the dominant lithologic unit found and cut by multiple dike-sill bodies of feldspar-rich andesite porphyry. A diorite stock intrudes the andesitic unit further southwest, and a thick limestone unconformably overlies the older rock units. A thin, but widely spread alluvial terrace gravel is found in lowlands further west. The area is traversed by NE- to NS-trending major faults. At least six known Au prospect areas occur within Greater Co'O and are similarly hosted by andesitic volcanics, related intrusive rocks, and characterized by quartz-sericite-chlorite mineral assemblage. Central Co'O is located within claimblock Chris-1 and Ebbe-3. The area is characterized by veins exhibiting a distinct multiple cymoidal loop pattern with vein widths ranging from a few centimeters to 9 m. At least three major vein systems generally trending EW and steeply dipping N are linked by complementary vein structures over a 200-300 m-wide zone traceable 900 m EW along strike.

The veins are enveloped by wide argillic (illitic) alteration. XRD analysis showed quartz + illite ± pyrite ± barite ± calcite are the major vein components. Pervasive silicification of wallrocks is represented by quartz + illite ± pyrite ± calcite. Silicification is central to a zone of wide argillic alteration characterized by illite + quartz ± calcite ± smectite ± leucocyte [leucoxene?] ± allophane. This is also pervasive in wallrock bordering the veins, and spatially grade to epidote + chlorite + quartz + illite ± pyrite ± calcite away from the zone of silicification. Hydrothermal breccia is commonly associated and occur as narrow, lensoid quartz breccia cemented by fine quartz.

Geologic reserve calculated from the three major structures was 600,000 tonnes at 10 g/tonne based on 100 m spaced drilling. Infill reserve drilling at 50 m sections will be completed in July and will be followed by an ore reserve recalculation.

The nature and style of mineralization in Co'O classify the deposit as epithermal and characterized by quartz-smectite-chlorite. Fluid inclusions Th analysis of quartz crystals yielded 200-260°C. Au deposition is interpreted as resulting from boiling of dilute hot neutral chloride fluids circulating at depth. The Co'O Au deposit is further classified as a low sulphidation epithermal Au deposit. (Authors' abstract)

DOMINY, S.C., 1989, Hydrothermal mineralization and alteration at Cligga Head, near Perranforth, Cornwall (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 52-53. Author at School of Geol. Sci., Kingston Polytechnic, Kingston upon Thames, U.K.

The striking feature of the stock is the development of an anticlinal/synclinal structure of veins within its core. Vein mineralization occurred contemporaneously with and after greisen wallrock alteration. It is essentially represented by a cassiterite, then cassiterite/wolframite phase and a final sulphide-chlorite phase. Fluid inclusions in quartz intergrown with the early cassiterite have ThL between 375-420°C and are moderately saline (4-10 eq. wt % NaCl), while quartz intergrown with the mixed cassiterite/wolframite phases have inclusion populations with a slightly lower Th 250-360°C with broadly similar salinities to the cassiterite phase.

The greisens (quartz and muscovite/Li-mica ± tourmaline) are developed in the wallrocks adjacent to the quartz veins and are seen to be closely spaced (3/5 per metre) sub-parallel bands with a thickness of 4-20 cm. These reach maximum intensity towards the centre of the stock where they merge into a pervasively greisenized core. Petrographic comparison between more or less greisenized material shows that orthoclase is the first feldspar to be hydrolysed and that albite is only destroyed in the more strongly altered samples. The process of greisenization is believed to be one of silicate hydrolysis and ion exchange. Fluid inclusion studies suggest that this takes place at ~275-375°C by fluids with salinities of 7-14 eq. wt % NaCl.

Argillic alteration is superimposed on earlier phyllic alteration assemblages and is developed in two main zones in the northern and southern portions of the stock. Alteration was accomplished in two stages. The initial phyllic alteration phase was represented by fluid T in the range 175-350°C with a salinity range of 8-15 eq. wt % NaCl during which albite was altered to sericite with some smectite and kaolinite. Silica was released from the system and reprecipitated as S quartz overgrowths and as barren quartz veins. Fluid inclusions in altered rock quartz and vein quartz show broadly similar Th and salinity ranges.

The second stage consisted of low T fluids (75-150°C, 2-10 eq. wt % NaCl) that interacted with the granite forming kaolinite from the phyllic assemblage. It is postulated that the kaolinized zones represent areas of relatively low T fluid flow within zones of relatively high permeability. (From author's abstract by E.R.)

DORIA, A., CHAROY, B. and NORONHA, F., 1989, Fluid inclusion studies in spodumene aplite-pegmatite dikes of Covas de Barroso, northern Portugal (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 25. First author at Centro de Geol. da Univ. Porto (INIC), Fac. Ciencias, 4000 Porto, Portugal.

In the Covas de Barroso area, numerous dikes of aplite-pegmatite crosscut metasedimentary micaschists of Silurian age. They are spatially and presumably genetically related to synorogenic Hercynian two-mica granites. Metamorphic conditions were: P 3 to 4 kbar and T ≈ 600°C. The strike of the dikes corresponds to the main regional structural trends. Many of these dikes support a discrete cassiterite mineralization.

Petrographic and geochemical studies have shown that some of these aplite-pegmatite bodies support a Li-rich mineral expression as spodumene and amblygonite, essentially present in the pegmatitic fraction, more rarely in the aplite. Time relationships are different: early in aplite, more vuggy in pegmatite. However, both are primary and associated with a Li-poor muscovite.

FI studies were carried out on quartz and spodumene in pegmatite. P and PS inclusions in spodumene are abundant. They are essentially H_2O-CO_2-bearing or crystal-rich inclusions, both intimately mixed. Tm CO_2 lies between -58.2 and -57.8°C. Th CO_2, always into the vapor phase, ranges between 16.2 and 20.3°C and suggests a low density. The average bulk Th L is about 290°C.

FI in the apparently contemporaneous quartz show different characteristics: the fluids are essentially H_2O-CO_2 (type L) or CO_2 (type V) bearing. Type L inclusions exhibit Tm CO_2 between -61.2 and -57.6°C, Tm ice from

-9 to -7°C, Tm clath 5 to 8°C, and Th CO_2 from 14.2 to 18.3°C into the vapor or liquid state, or by meniscus fading. In type V inclusions, Tm CO_2 varies between -59.7 to -59.3°C, Th CO_2 around 16.4°C in liquid, sometimes by meniscus fading.

Preliminary Raman investigation on type L inclusions reveals the following bulk composition: X H_2O = 80 mole %, X NaCl = 1 mole %, X CO_2 = 16 mole %, X CH_4 = 2 mole %, X N_2 = 1 mole %. The bulk density of the fluid is 0.68 g/cm^3.

Similar fluids with such discrepancies between the P fluids trapped in apparently contemporaneous minerals have already been evidenced in spodumene-rich cores of Li-pegmatites. Immiscibility phenomena during a continuous decrease in T are invoked, but mixing of fluids from different origins is also possible. (Authors' abstract)

DOROBEK, Steve, 1989, Migration of orogenic fluids through the Siluro-Devonian Helderberg Group during late Paleozoic deformation: Constraints on fluid sources and implications for thermal histories of sedimentary basins: Tectonophysics, v. 159, p. 25-45.

FI date and fracture-filling cement fabrics in deformed, but non-overthrusted, carbonate and siliciclastic rocks of the Siluro-Devonian Helderberg Group, central Appalachians, indicate post-cementation, late Paleozoic migration of high P, high T fluids.

Void-filling quartz and calcite cements contain S, two-phase FI (L + V) which occur in annealed microfractures. Most Tm (last occurrence of ice) are -20° to -25°C, which correspond to salinities of >22 eq. wt % NaCl. P-corrected L-V Th are 200° to 300+°C and greatly exceed maximum paleotemperatures (~150°C) given by conodont CAI values, vitrinite reflectance, illite crystallinity, or T calculated from known sedimentary overburden.

Completely cemented sandstone and limestone also have multiple crosscutting trains of S hydrocarbon I. Hydrocarbon I occur along deformation microstructures in cements. Some hydrocarbon I trains crosscut cement-filled fractures. The nature of occurrence of the S I suggests that fluids moved along intracrystalline deformation microstructures either during or after late Paleozoic deformation.

Rare fractures contain transported skeletal grains, "exotic" clasts (lithologies different from wall rock), re-cemented clasts of fracture-filling cement, and mud. Cement clasts contain solid I of mud and skeletal fragments, and indicate several episodes of particle transport, cementation, and refracturing prior to final fracture filling and cementation. These fracture fills locally crosscut stylolites. Coarse-grained, poorly sorted, "clastic fracture fills" suggest migration of rapidly moving fluids which were capable of transporting clasts through fracture conduits under deep burial conditions.

Conduction calculations place upper limits on size and duration of thermal anomalies which were caused by extrabasinal fluids. These calculations indicate that hot fluid migration events most likely were short-lived. Heat transfer by extraformational fluids moving along faults and fractures may have been the mechanism by which thermal anomalies developed in the Helderberg Group. Stratigraphic constraints suggest that likely sources for the hot brines are overthrusted terranes to the east of the study area. Possible stratigraphic horizons which were sources for the overpressured, hot fluids may have been thick Cambrian shales which are important detachment horizons for major, late Paleozoic thrust sheets in the eastern Valley and Ridge province (east of the study area). Fluids may have migrated during thrusting, along thrust faults which ramp upwards from east to west into stratigraphically higher units; thrust faults ultimately die out in Devonian units. Some of the dissolved ions in the S two-phase I may have been incorporated when shale-derived fluids moved through Silurian evaporites or Cambro-Ordovician carbonates which contain evidence of cryptic evaporites. Potential source rocks for S hydrocarbon I may have been Lower Silurian through Lower Devonian strata, based on Lopatin modeling and assuming that migration occurred during late Paleozoic deformation.

This study may help to explain many apparently anomalous geologic phenomena in deformed foreland basin sediments. It also has implications for tracking migration pathways for fluids which facilitate regional scale deformation in fold-and-thrust belts and how "tectonic fluids" may affect the rocks through which they move. (From author's abstract)

DOUMA, Jan, 1989, The representability of cracked media by periodically layered media: Geophysical Prospecting, v. 37(7), p. 831-849. Author at Rijksuniv. Utrecht, Dept. Explor. Geophys., Inst. Earth Sciences, Utrecht, The Netherlands.

Indexed under FI. (E.R.)

DOVE, P.M., CRERAR, D.A., BERGER, G. and **SCHOTT, J.**, 1989, The influence of pH on the hydrothermal dissolution kinetics of quartz in solutions of electrolyte and transition metals (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A164.

DOYLE, J.A. and **BODNAR, R.J.**, 1989, Effect of fluid immiscibility in the system H_2O-CO_2-NaCl on the reaction calcite + quartz + rutile = sphene + CO_2 at 2 kbar (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A155.

DRUMMOND, S.E., PALMER, D.A., WESOLOWSKI, D.J. and **GIORDANO, T.H.**, 1989, Hydrothermal transportation of metals via acetate complexes (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-420.

DU, Letian, 1989a, Mantle ichor HACONS—Evidence of its existence (I): Chinese J. Geochem., v. 8, no. 3, p. 193-201 (in English). Author at Beijing Geology Research Institute of Nuclear Industry, P.R.C.

A HACONS, mantle fluid, has been proposed in the light of current knowledge concerning Diwa, rift, asthenosphere, anomalous and depleted mantle, plume, percolating magma fluid, degassing, inorganic origin of some oil and gas, hypogenic salt deposits, alkali-metasomatism in hydrothermal deposits and experimental studies of basalts. The HACONS fluid originated from the mantle and is composed of hydrogen and halogens (H), alkalies (A), carbon (C), oxygen (O), nitrogen (N) and sulfur (S) compound systems. Aluminosilicate magmas are expected when the HACONS fluid reacts with solid rocks. Many geological processes, including tectonism, magmatism, volcanism, metamorphism, hydrothermal activity, thermal sedimentation and related mineralizations are thought to be controlled to a certain extent by large-scale movement of HACONS fluid in the earth's interior. The asthenosphere is essentially a layer with abundant HACONS fluid. (Author's abstract)

See also Du, 1988, Fluid Inclusion Research, v. 21, p. 103. (E.R.)

DU, Letian, 1989b, Mantle ichor HACONS—Evidence of its existence (II): Chinese J. Geochem., v. 8, no. 3, p. 202-212 (in English). Author at Beijing Geology Research Institute of Nuclear Industry, P.R.C.

The chemistry and migration patterns of the mantle ichor are discussed on a global scale followed by evaluations of the significance of HACONS fluid with respect to various geological processes of fundamental interest. (Author's abstract)

DUBESSY, J., 1989, The C-O-H-N-S system studied from fluid inclusion analysis by micro-Raman spectrometry: Methodology, chemical equilibrium and disequilibrium (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-421. Author at CREGU, Vandoeuvre Les Nancy, France.

Achievement of chemical equilibrium between rock-forming minerals and fluids which percolate through them is the key point for deciphering mass transfer reactions. Redox reactions are known to be slow, and kinetics of homogeneous and heterogeneous equilibria in the C-O-H-N-S system are still poorly known. Analysis of molecular species from fluid inclusions of the C-O-H-N-S system by micro-Raman spectrometry can give some constraints on the conditions required for chemical equilibrium in this system. Therefore, the following points are examined in this paper: (1) the analysis of gas species by micro-Raman spectrometry; (2) the meaning of fluid inclusion composition determined at room T; and (3) natural evidences of chemical equilibrium and disequilibrium.

Analysis of fluid inclusions by micro-Raman spectrometry: (A) Multichannel versus single channel detectors are compared. (B) Refractive index of the immersion medium (air, water, oil) between the sample and the objective are compared. Calculations of the optical paths are carried out as a function of n_i and the depth of the inclusion. (C) The depolarization of the bands resulting from birefringent minerals and the beamsplitter is discussed. (D) Calculations of the effect of the scattering geometry on the ratio of Raman scattering cross-sections is shown to be negligible because of the very low value of the depolarization ratio of the Raman bands of the common gases. (E) The density and composition dependence of Raman scattering cross-sections (σ). Although such experimental determinations of σ are still lacking at this time, this parameter is expected to exhibit the highest variations for CO_2 if a single band is taken [into] account, because of the Fermi resonance. Therefore, measurements of the two CO_2 bands is for the moment the only way to minimize this effect.

Meaning of fluid inclusion compositions determined at room T: As the equilibrium constants are strongly temperature dependent, one can question the differences between the V-X properties measured at room T, $(V, X)_o$ and $(V,X)_{P,T}$ at P,T trapping conditions under chemical equilibrium. Thermodynamic calculations show that V, X properties are not strongly affected by this reequilibration effect. However, calculations show that the lower the fluid density is, the greater the modifications are. Differences in log fO_2 and log fS_2 determinations from $(V, X)_o$ and $(V,X)_{P,T}$ properties are around 0.1 log units.

H_2 is often considered to diffuse out through the host crystal after trapping and consequently to modify the CO_2/CH_4 ratio. First, several natural evidences of H_2-bearing fluid inclusions from different environments and host minerals (quartz, chkalovite, pyroxene) indicate that H_2 does not diffuse out [of] inclusions as easily as is often claimed. Secondly, thermodynamic calculations show that H_2 leakage does not change significantly the CO_2/CH_4 ratio due to a high internal buffering capacity of homogeneous chemical equilibria in the C-O-H system.

Natural evidences of chemical equilibrium and disequilibrium: Fluid-graphite equilibrium fixes an upper limit to fO_2 close to Q-F-M and Ni-NiO in the 300-700°C range and controls partly the gas concentration and therefore the static dielectric constant of the fluid. Both of these parameters are critical for metal transport by hydrothermal and metamorphic fluids (Dubessy et al., 1987). The composition of fluid inclusions, some of them with a trapped graphite crystal and others, without graphite, show that the fluid-graphite equilibrium has been efficient down to 300°C during cooling inside the inclusion. By contrast, a minimum T of 400°C seems to be required as shown on a paleo-geothermal system around an intrusive granite through an epimetamorphic series (Ramboz et al., 1985). The lack of evidence of graphite dxls in fluid inclusions of the C-O and C-O-H-N-S system confirms that the nucleation of graphite is characterized by a high activation energy.

Strong chemical disequilibrium have been found in fluid inclusions associated with several U deposits formed below 300°C. Gas compositions showing chemical disequilibrium are the following: H_2-O_2, H_2-CH_4 (Dubessy et al., 1988), CO_2-CO-H_2 without CH_4. Radiolytic processes are involved in the formation of these fluid compositions. (From author's abstract by E.R.)

DUBESSY, J., BASTOUL, A.M. and **LANDAIS, P.**, 1989, Graphite-fluid equilibrium or disequilibrium: A discussion (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 26-27. Authors at CREGU, BP-23, 54501-Vandoeuvre, Cedex, France.

The achievement of chemical equilibrium between fluids and graphite as well as the reactivity of graphite are critical in fluid geochemistry in geothermal and metamorphic contexts. Indeed fluid-graphite equilibrium fixes an upper limit to the oxygen fugacity and implies the presence of gases, such as CO_2 and CH_4, which decrease the fluid density and the static dielectric constant. These parameters partially control fluid circulation and the stability of ion-pair complexes. (...)

In the Tichka Au deposit from Morocco, two types of FI with the same microthermometric data located within the same quartz crystal have been found. Inclusions with a graphite crystal, identified by micro-Raman spectroscopy, do not show any CO_2, whereas inclusions without graphite exhibit very small CO_2 concentrations. Thermodynamic calculation of FI composition during their cooling history after trapping, shows that CO_2 must be present in graphite depleted inclusions whereas its concentration drops down to very low values, below the detection limit, if graphite is present and at chemical equilibrium with the fluid phase. In addition, the highest T of graphite-fluid chemical equilibrium is estimated to be ~280-300°C from the maximum CO_2 concentration calculated from the limit of detection in the graphite-bearing FI. Although the T-time path during the cooling history of these inclusions is unknown, this T is considerably lower than the 400-425°C determined on the paleo-geothermal system: this results mainly from differences in fluid residence time. Around a cooling intrusive, the fluid residence time at T ~400°C is in the order of thousands of years.

In the alteration zone of graphite-bearing granulitic gneisses associated with U deposits, strong graphite alteration has been evidenced from Raman spectrometry and TEM studies (Wang et al., 1989, in press). Thermodynamic reconstruction of fluid geochemistry responsible for the alteration zone has shown that the alteration fluids have circulated at ~200-250°C and that they were acidic (pH = 4) and sulphate-rich. Acidic sulphate-bearing fluids are known by chemists to form intercalation compounds which can strongly disorganize the graphite structure. Although such compounds have not been identified in the present case study, the alteration of these graphites is tentatively attributed to this fluid circulation which probably lasted several hundreds of thousands of years.

In conclusion, no general rule can be edicted on the reactivity of graphite as well as the achievement of chemical equilibrium with fluid phases. Fluid residence time, fluid composition especially the sulphate concentration, pH, and T have to be considered in each case. (From authors' abstract by E.R.)

DUBESSY, Jean, POTY, Bernard and RAMBOZ, Claire, 1989, Advances in C-O-H-N-S fluid geochemistry based on micro-Raman spectrometric analysis of fluid inclusions: Eur. J. Mineral., v. 1, 517-534. First author at CREGU, GS-CNRS-CREGU, B.P. 23, F-54501 Vandoeuvre Cedex, France.

The first part of this paper focuses on the analysis of fluid inclusions by micro-Raman spectrometry. SO_4^{2-} and HS^- are the only polyatomic anions identified by this technique. Na^+, Ca^{2+}, Mg^{2+}, Fe^{2+} cations can be identified by the Raman spectrum of the corresponding salt hydrate which nucleates on cooling. Gas analysis is the most fruitful field of application of micro-Raman spectrometry. Errors in the reconstruction of the bulk V-X properties of gas-bearing fluid inclusions, arising either from Raman analysis or from the quantitative interpretation of phase equilibria, are discussed.

Geochemical constraints inferred from these analyses are considered in the second part. The V-X properties of fluids in the C-O-H-N-S system are deduced mainly from room-T measurements. They are shown to be representative of the fluid V-X properties in the P-T conditions of trapping, and thus, to yield representative fO_2 and fS_2. The paleo-redox state of fluids associated with U, Sn, W, and Au deposits is shown partly to account for the contrasted behaviour of these metals at the hydrothermal stage. Gas concentration is a key parameter for controlling metal transport and deposition properties of fluids. This is because it controls the static dielectric constant of the fluid, which in turn constrains the ion-pair stability. It is shown that some N_2-bearing fluids may be the end product of major redox reactions. Finally, the H_2- and O_2-bearing fluid inclusions formed in three U deposits provide evidence for water radiolysis by alpha particles. (Authors' abstract)

DUBROVICH, N.A., 1989, Crystallization of supercooled water drops stimulated by infrared resonance radiation of ice: Doklady Akad. Nauk SSSR, v. 307, no. 3, p. 568-570 (in Russian). Author at Hydrometeorological Inst., Leningrad, U.S.S.R.

Pertinent to H_2O metastability during freezing studies of fluid inclusions. (A.K.)

DUKE, E.F., GALBREATH, K.C. and TRUSTY, K.J., 1989, Fluid inclusion and carbon isotope studies of quartz-graphite veins, Black Hills, South Dakota and Ruby Range, Montana (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 22. Authors at Inst. for Study of Min. Deposits, South Dakota Sch. Mines and Tech., Rapid City, SD 57701-3995.

The existence of crosscutting graphite veins in high-grade metamorphic rocks provides strong evidence for transport of C-bearing fluids along fractures in the mid-crust. Graphite veins in Precambrian rocks from the Black Hills, South Dakota, and the Ruby Range, Montana, are being studied by FI and stable isotope techniques to assess P-T conditions of vein formation, possible sources and compositions of vein-forming fluids, and graphite precipitation mechanisms.

In the Black Hills occurrences, peak metamorphic conditions are estimated at 550°-600°C, 4-6 kbar. FI in quartz associated with the graphite veins are predominantly H_2O-CO_2 mixtures with low to moderate salinities (3-95 mol % CO_2, ~0-11 wt % NaCl eq.). Combined microthermometry and laser Raman microanalysis indicate that additional components are minor (maximum 13 mol % CH_4 and 5 mol % N_2). Isotope analysis of eight graphite samples from one occurrence yielded homogeneous $\delta^{13}C$ values of $-20.7 \pm 0.2‰$, suggesting that the bulk of this carbon was mobilized from reduced organic carbon in associated metasedimentary rocks.

In the Ruby Range, peak metamorphic conditions were higher, ~750°-800°C, 5-8 kbar. FI in graphite-free veins are nearly pure CO_2 with less than ~5 mol % CH_4 eq. ($CH_4 + N_2$). Inclusions in graphite-bearing veins, however, commonly contain 20-40 mol % CH_4 eq. with one sample containing >75 mol ‰ CH_4 eq. $\delta^{13}C$ values for the vein graphites fall in a restricted range from -6.2 to -8.6‰. Disseminated graphite from nearby marble ranges from -4.8 to -6.8‰. The relatively uniform and heavy isotopic character of the vein graphite is consistent with mobilization of C from the marbles via a fluid phase. However, the existence of one vein with $\delta^{13}C$ (graphite) = -19.5‰ and extremely CH_4-rich FI suggests that another carbonic fluid, perhaps derived from organic matter in metapelites, was locally present. (Authors' abstract)

See also Duke and Galbreath, 1987, Fluid Inclusion Research, v. 20, p. 97-98. (E.R.)

		MICROTHERMOMETRY				LRM [1]				
TYPE	n	X_{H_2O}	X_{CO_2}	X_{CH_4} [3] equiv.	wt.% NaCl eqiv.	n	X_{CH_4}	X_{N_2}	$\overline{V}$ [3] ($cm^3 mole^{-1}$)	$\delta^{13}C$ graphite [2] (permil)
Black Hills										
FMI	56	.24-.92	.08-.75	0-.03	4-11	2	<.01	.02-.03	22-49	- 20.7
FMII	4	0	.95	.05-.06	-	0	n.d.	n.d.	50-55	
FMIII	14	0	1.00	0	-	2	tr.	0	58-122	
PT	10	.65-.89	.10-.27	.01-.08	-	2	.08-.13	.01-.02	14-22	n.d.
NP	29	.75-.97	.03-.23	.01-.02	0-2	2	.01	.03-.05	11-19	n.d.
Ruby Range										
CI	32	0	.95-.98	.02-.05	-	0	n.d.	n.d.	58-62	-
CII	64	0	.53-.95	.05-.47	-	0	n.d.	n.d.	52-89	- 6.2-
CIII	6	0	.64-.72	.28-.36	-	0	n.d.	n.d.	41-43	- 8.6
CIV	34	0	<~.25	>~.75	-	0	n.d.	n.d.	n.d.	- 19.5
CV	47	1.00	0	0	13-32	0	n.d.	n.d.	19.1-19.7	-

1) With R.C. Burruss, U.S.G.S., Denver; σ = 1.5 (CO_2), 7.0 (CH_4), 1.0 (N_2).
2) With P.I. Nabelek, Univ. Missouri-Columbia.
3) Calculated from Heyen et al. (1982), Darimont and Heyen (1988), and van den Kerkhof (1988).
n = number of inclusions; n.d. = not determined; tr = trace.

DUNBAR, N.W., HERVIG, R.L. and **KYLE, P.R.**, 1989, Determination of pre-eruptive H_2O, F and Cl contents of silicic magmas using melt inclusions: Examples from Taupo volcanic center, New Zealand: Bull. Volcanol., v. 51, p. 177-184. First author at Dept. Geoscience, New Mexico Inst. Mining and Tech., Socorro, NM 87801.

Water, F, and Cl contents of melt inclusions in phenocrysts from the 2-ka-old Taupo and Hatepe plinian tephras, and the ~22-ka-old Okaia tephra from the Taupo volcanic center, New Zealand, were measured by electron and ion microprobe. Major and trace element chemistry of the inclusions is similar to that of bulk rock, supporting our assumption that volatile contents of inclusions are representative of the magma in which the crystals grew. Inclusions in the 2-ka Taupo plinian tephra contain a mean of 4.3 wt % H_2O, 450 ppm F, and 1700 ppm Cl; from the Hatepe plinian tephra 4.3 wt % H_2O, 430 ppm F, and 1700 ppm Cl; and from the Okaia tephra 5.9 wt % H_2O, 470 ppm F, and 2100 ppm Cl. Sulfur was below the detection limit of 200 ppm. The constant H_2O, F and Cl from a number of stratigraphic horizons in the tephra deposits suggest that the Taupo and Hatepe plinian tephras (>8.2 km^3 magma volume) were derived from a magma body that did not contain a strong volatile gradient. By inference, there is no pre-eruptive volatile difference between these plinian eruptions and a phreatoplinian eruption which occurred between the two. Virtually no major element zonation is seen in this eruptive sequence. Although the Okaia tephra was also erupted from the Taupo volcanic center, probably from a similar vent area, its higher volatile contents and distinct composition as compared to the Taupo tephras show that it was derived from a different, and possibly deeper, magma body. (Authors' abstract)

DUNBAR, N.W. and **KYLE, P.R.**, 1989, Volatile contents of obsidian from the Taupo Volcanic Zone, New Zealand, and implications for eruption processes (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 77. Authors at Geoscience Dept., New Mexico Inst. Mining and Technology, Socorro, NM 87801.

Obsidian in 0.01 to 20 ka rhyolitic tephra deposits from the Taupo Volcanic Zone, New Zealand, contains elevated and variable H_2O (0.2 to 2.5 wt %) and Cl (0.12 to 0.18 wt %) contents compared to rhyolitic dome obsidians which quenched at surface P (~0.1 wt % H_2O , ~0.1 wt % Cl). Major and trace element analyses of the obsidian in the tephra are similar to their associated tephra, suggesting that they are co-genetic. The clear, glassy appearance of the obsidian, their high release T of H_2O, and O isotopic composition of +7‰ indicate that the H_2O contained in the obsidian is magmatic, rather than meteoric H_2O introduced after the tephra was deposited. However, the obsidian contains less H_2O and Cl than the primary non-degassed Taupo Volcanic Center magmas, which are determined to be ~4.3 to 5.9 wt % H_2O and ~0.18 to 0.24 wt % Cl based on ion and electron microprobe analyses of melt inclusions. Therefore, the obsidian in the tephra deposits is thought to represent partially degassed, quenched P magma.

There is a rough correlation between the H_2O and Cl contents of obsidian which suggests that the magmatic Cl partitioned into an H_2O-rich fluid phase during eruptive degassing. This correlation can be projected to include the H_2O and Cl contents of melt inclusion and can be used to determine a partitioning coefficient for Cl between the vapor and the melt of ~5.5.

Using a pre-eruptive H_2O content for Taupo magma of 4.3 wt %, and Burnham's (1970) H_2O solubility model, the P and depth of initial vesiculation of the magma can be calculated, and occurs at ~0.9 kb or ~3.5 km depth. Initial fragmentation (assumed to occur at a vapor:melt ratio of 3:1) will begin at 0.1 kb or ~500 m depth. Obsidian in most of the tephra deposits contains less than 1 wt % H_2O, and based on this, the P and depths of obsidian formation were calculated and were determined to be generally <0.1 kb or 500 m. Therefore, the obsidian in these tephra deposits collapsed and quenched from expanded, fragmented magma. H isotopic analyses of H_2O in the obsidian suggest open-system degassing, which supports formation of obsidian from fragmented melt. The variable H_2O contents of obsidian fragments in a single deposit indicate that quenching occurred over a range of depths. This, and the strong alignment of microphenocrysts in obsidian, suggests that fragmented magma was welded onto the conduit walls during eruption, cooled to form obsidian, then incorporated into the tephra.

A tephra with a strongly phreatomagmatic character, the Hatepe phreatoplinian tephra, erupted from the Taupo Volcanic Center ~2 ka B.P., contains many individual obsidian fragments with high H_2O contents. Many obsidian fragments contain >2.0 wt % H_2O, and some fragments ≤2.5 wt %. The highest H_2O content corresponds to a quench P of 0.35 kb or a depth of 1.5 km. The anomalously high magmatic H_2O of obsidian in the Hatepe phreatoplinian tephra as compared to obsidian in plinian tephras from the Taupo Volcanic Center suggests that the meteoric H_2O responsible for the phreatomagmatic nature of this eruption may have also influenced the deep quenching of obsidian. This implies that meteoric H_2O may have interacted with the magma at depths of up to 1.5 km to cause this phreatomagmatic eruption. (Authors' abstract)

DURAN, M.E., LOREDO, J. and GARCIA IGLESIAS, J., 1989, Fluid inclusion study of quartz and beryl from granitic pegmatites in N.W. Salamanca, Spain (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 28. First author at Dpt. GPPG, Fac. Geol., Univ. Barcelona, C/Marti i Franques s/n, 08028 Barcelona, Spain.

FI in quartz and beryl from granitic pegmatites of Perena and Fegeneda in N.W. Salamanca, Spain, have been evaluated in order to define the cooling trend and fluid evolution.

The Be-rich, internally zoned Perena Pegmatite (PP) is hosted and genetically related to Hercynian two-mica and muscovitic granites. Its paragenesis consists of beryl, feldspars, muscovite and quartz in the inner part; these minerals are accompanied by tourmaline, chlorite and bertrandite in the intermediate zone; and feldspars, muscovite and quartz in the outer zone.

The Li-rich Fregeneda Pegmatite (FP) is a dike hosted by a pre-Ordovician, metasedimentary sequence and is related at depth to two-mica granites. Essential minerals are spodumene, lepidolite, feldspars and quartz. Both pegmatites show two types of FI:

(i) Mixed H_2O-CO_2 inclusions (*PP-Beryl*: Te, -60 to -55°C; Tm ice -8 to 0°C; Tm clath 6 to 9°C; Th CO_2 24 to 29°C; Th L 160 to 320°C; *PP-quartz*: Te -60 to -55°C; Tm ice -6 to 0°C; Tm clath 6 to 10°C; Th CO_2 23 to 28°C; Th 150 to 340°C, homogenization to liquid, vapor or critical point; *FP-quartz*: Te -60 to -56°C; Tm ice -10 to -1°C; Tm clath 6 to 13°C; Th CO_2 21 to 26°C; Th L 190 to 380°C).

(ii) Aqueous inclusions (*PP-beryl*: Tm ice -4 to 0°C; Th 180 to >460°C, homogenization to liquid, vapor and critical point; *PP-quartz*: Tm ice -6 to -5°C; Th 130 to 370°C, homogenization to liquid, vapor or critical point; *FP-quartz*: Tm ice -4 to 0°C; Th L 215 to 320°C).

The FI data coupled with the reaction relationships in the system $LiAlSiO_4$ (London, 1986, Am. Min., 71, 376) and the characteristics of the granites associated with the pegmatites studied suggest that their development occurred between 550 and 400°C and between 2.5 and 1.5 kb from CO_2-bearing, solute-poor, low-density, aqueous fluids in the transition from magmatic to hydrothermal conditions. (Authors' abstract)

DURASOVA, N.A., BELAEVA, V.K., KOCHNOVA, L.N., IGNATENKO, K.I. and VASIL'YEV, Ye.N., 1989, Copper migration in aluminosilicate glasses on heating as a possible source of copper mineralization: Doklady Akad. Nauk SSSR, v. 308, no. 1, p. 164-167 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci. of USSR, Moscow, U.S.S.R.

In aluminosilicate glass, grains (dia. 150-500 µm) bearing mostly monovalent Cu (0.3-0.4 wt % as CuO), after heating in air at 500°C for 45 hours, Cu migrated from the grain center to the grain surface, forming CuO on the surface; after the runs the central parts of the grains contained 0.1-0.2 wt % Cu as CuO. Pertinent to the melt inclusion studies. (A.K.)

DURISOVA, Jana, 1989, Diversity of fluids in the formation of ore assemblages in Bohemian massif (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 3. Author at Geol. Survey, Malostranske nam. 19, 118 21 Praha 1, CSSR.

FI in minerals from various ore assemblages in the Czech part of the Bohemian massif were studied by optical microthermometry and in selected samples by Raman spectroscopy.

Sn and W veins and greisen deposits from the Saxo-Thuringian zone related to the early hydrothermal post-magmatic activity of Variscan granitic plutons were formed between 500 and 300°C from chloride solutions containing NaCl as the main component. Two types of fluids were ascertained: the first one of high salinity (35-40 wt % NaCl eq.), and the second one of low salinity (2.5-10 wt % NaCl eq.) and of low density. The occurrence of these two unmixing fluids is typical, CO_2 is present only in negligible amounts (few mol %).

Hydrothermal Pb-Zn deposits related to deep structures (Pribram) and fluorite-barite veins without an apparent relationship with magmatism originated from fluids of moderate-to-high salinity (9-25 wt. NaCl eq.) and complex composition (Na, Ca, Mg salts), which did not contain CO_2. Fluorite deposits were formed in the T range 110-150°C, whereas polymetallic veins were formed at 100-200°C.

The massive sulphide ores (Jeseniky Mts., Celina, Mokrsko, Orlik near Humpolec) contain fluids characterized by the presence of H_2O, CO_2, CH_4, and N_2. High density of CO_2 from 500 to 960 kg/m^3 is common and corresponds with metamorphic conditions. A change in the fluid composition with metamorphic grade is evident. With decreasing of metamorphic grade, CO_2 diminishes, methane appears and the amount of water is continuously increased. The salinity of fluids varied from 5 to 20 wt % NaCl eq. The Au was apparently deposited in the course of metamorphic processes. FI study indicates a rapid change of fluid composition caused by the reduction and transition of CO_2 into CH_4. This change may have been the principal cause for the Au deposition which occurred in the T interval from 380 to 250°C. (Author's abstract)

DURISOVA, J. and SZTACHO, P., 1989, A fluid inclusion study of different types of gold deposit in the Bohemian Massif, Czechoslovakia (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 29. Authors at Geol. Survey, Malostranske nam. 19, 118 21 Praha 1, Czechoslovakia.

The presence of Au-mineralization is one of the significant metallogenic features of the Bohemian Massif. Au deposits, in the form of quartz veins and stockworks (deposits Celina, Mokrsko, Jilove), are concentrated in the central Bohemian metallogenic zone in low-grade metamorphosed volcano-sedimentary rocks of Proterozoic age intruded by the Variscan central Bohemian pluton. The Au deposits of the northeastern part of the Bohemian Massif occur in regionally metamorphosed Devonian rocks within stratiform base metal deposits (Zlate Hory), in quartz veins (Zlaty Chlum) and disseminated in black shales (Sucha Rudna). Au mineralization is the core of the Bohemian Massif occurs in high-grade metamorphic rocks of the Moldanubicum in stratiform lenses and discordant quartz veinlets (Kasperske Hory, Orlik). In the central Bohemian zone and in the Moldanubicum, Au is accompanied by scheelite.

Au-bearing quartz from all the deposits contain inclusions of the H_2O-CO_2 type (10-40 mole % CO_2) with small amounts of CH_4 ($\leq$3 mole %) and N_2 ($\leq$2 mole %). The density of CO_2 (0.59-0.97 g/cm^3) corresponds with the grade of regional metamorphism. Solutions are of low salinity (3-10 wt % NaCl eq.). Phase separation occurred in some deposits as evidenced by variable H_2O:CO_2 ratio in adjacent FI whose Th are similar. These inclusions indicate the T range of Au quartz deposition between 250-360°C. FI of H_2O-CH_4 type (10-60 mole % CH_4) appear to be of later origin and were found only at Zlate Hory and Orlik. Inclusions of H_2O type occur in quartz of all the deposits, are mostly S in origin and contain chloride solutions (salinity 3-15 wt % NaCl eq., Th 130-300°C).

Scheelite from the Orlik stratiform deposit is free from H_2O-CO_2 inclusions. Inclusions of H_2O type with moderate salinity (3-15 wt % NaCl eq.) and Th in the range from 200 to 403°C are typical (boiling fluid at 364-386°C was observed). The CH_4-rich inclusions, probably of S origin, are also observed.

The FI study indicates that the Au-bearing quartz from the various styles of mineralization in the Bohemian Massif were deposited from solutions of similar composition. Analogous fluids were observed in rock-forming quartz in host rocks of various metamorphic grade. It is assumed that the quartz was either formed or affected by the fluids associated with the metamorphic processes. (Authors' abstract)

EADINGTON, Peter, 1989, Oil migration and thermal history in the Eromanga Basin: New constraints from fluid inclusions, CSIRO (Australia) Exploration Research News, v. 2, p. 12-13.

Timing of hydrocarbon migration and thermal and burial history of sedimentary rocks determined from fluid inclusion measurements can be used in evaluation of petroleum charge to drill targets. Fluid inclusion data also provide a direct test of the results of chemical modelling of oil generation. (Author's abstract)

EADINGTON, P.J., HAMILTON, P.J. and **GREEN, P.**, 1989, Fluid inclusion and stable isotope investigation of diagenesis and oil migration in the Hutton sandstone, S.W. Queensland (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-466. First author at CSIRO Div. Exploration Geoscience, North Ryde, Australia.

Fluid inclusion T, thermal maturities, stable isotope measurements and chemical kinetic modelling have been combined to investigate the diagenetic and hydrocarbon fluid history of the Jurassic Hutton sandstone in the Eromanga Basin, southwest Queensland.

The sequence of diagenetic minerals and their O isotope composition in $\delta^{18}O$ notation relative to SMOW is siderite (11.9‰), followed by kaolin (7.67 to 9.58‰) then quartz overgrowths (13.4 to 14.6‰) and dolomite. The $\delta^{13}C$ PDB composition of siderite is -7.04‰.

Siderite, the earliest formed cement, formed at ~55°C from parental groundwater that was little modified in O isotope composition from surface water at the time ($\delta^{18}O$ -11 to -13‰). If fluid inclusion T are used for mineral-H_2O isotope fractionations then the ^{18}O compositions of formation H_2O increased to -6‰ for formation of quartz overgrowths. Kaolinite precipitated at T and O isotope compositions between those of siderite and quartz.

This trend of increasing ^{18}O content parallels the normal diagenetic trend for evolving pore fluids in sedimentary basins. Subsequent uplift has changed fluid flow patterns as evidenced by a reversal in the ^{18}O content of modern groundwaters to about -8‰ at the present day.

Quartz overgrowths have trapped drapes of clays that sometimes fluoresce (adsorbed hydrocarbons?) and aqueous fluid inclusions at the boundary with the detrital core. Liquid hydrocarbon inclusions, identified by their fluorescence, occur mostly in late fractures in quartz grains, but occur at the boundary of detrital core and overgrowth in two samples. Therefore hydrocarbon migration in part overlapped and in part followed formation of quartz overgrowths.

Fluid inclusion Th and isochores indicate quartz overgrowths were formed at 91 to 116°C and dolomite crystallized at ~114°C. These T assume formation of the diagenetic minerals at depths 300 m greater than the current depths. This amount of erosion and the fluid isochores indicate a geothermal gradient about 4.5°C/100 m in the mid Cretaceous, similar to the current gradient. Erosion associated with the Eocene-Miocene folding is assumed.

Calculated maturities using the fluid inclusion T (constant geothermal gradient) are significantly greater than vitrinite reflectances and Rockeval Tmax values for formations just above and below the Hutton.

If organic metamorphism is measured in terms of progress of oil generating reactions using kinetic modelling then the current geothermal gradient and fluid inclusion T result in calculated oil yields that indicate late Cretaceous to early Tertiary oil migration. This closely follows the formation of quartz overgrowths and is consistent with the petrography of liquid hydrocarbon inclusions. It is also consistent with some structures being only partly filled with oil since structures of Eocene age formed at a late stage of oil generation. (From authors' abstract by E.R.)

EARY, L.E., 1989, Solubility of amorphous arsenic sulfide from 25 to 90 degrees C (abst.): Eos, v. 70, p. 1382.

EGGLER, D.H., 1989, Influence of water and carbon dioxide on melt and fluid chemistry in subduction zones: NATO ASI Ser., Ser. C, 258 (Crust/Mantle Recycl. Convergence Zones), p. 97-104 (Eng.). Author at Geosciences Dept., Pennsylvania State Univ., University Park, PA 16802.

Volatiles can be transferred from slabs to wedge asthenosphere either by silicate melts or by hydrous fluids. Expts. defining the nature of these agents, and expected ratios of transported elements, are not well-constrained, esp. for fluids. Phase equil. of basaltic slab material and probable geotherms suggest that slabs devolatilize or melt, or both, at depths shallower than the av. 136 km beneath arc fronts. Volatiles probably are transported into immediately overlying asthenosphere and then carried by flow beneath arcs. Simple addn. of probable fluid to MORB (Mid-Ocean Ridge Basalt) or OIB (ocean island basalt)-type asthenosphere cannot explain obsd. H_2O and K_2O to asthenosphere and more complicated histories of melt generation; the melts generated at 100-140 km beneath arcs bear little chem. relation to arc basalts. Volatiles thus must pass numerous "filters" before they emerge in arc volcanic rocks. (CA 112:220605x)

ELDERS, W.A., McKIBBEN, M.A. and **WILLIAMS, A.E.**, 1989, Salton Sea Scientific Drilling Project: Metamorphism and ore genesis in action (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-445-446.

ELDRIDGE, C.S. and **McKIBBEN, M.A.**, 1989, Radical $\delta^{34}S$-zonation in epithermal pyrite: A SHRIMP study in the boiling zone (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A360. First author at RSES and Geology Dept., Australian Nat'l Univ., Canberra, Australia.

Continental Scientific Drilling Project borehole VC-2a penetrated a now vapor-dominated zone of acid-altered volcanics, located beneath Sulphur springs at the western edge of the resurgent dome in Valles Caldera, New Mexico. Within the upper 100 m of the borehole, hydrothermal veins and vugs contain S pyrite, molybdenite and other base metal sulfides along with quartz, fluorite and sericite. (....)

The rapid shifts from positive to negative $\delta^{34}S$ values in the zoned pyrites support a model for sulfide deposition accompanying volatile loss and preferential oxidation of $H_2{}^{34}S$ during boiling. The isotopically homogeneous, ≈0‰ pyrite may have formed early, prior to extensive boiling. Crystals composed of homogeneously light sulfur may have precipitated late, from the devolatilized, residual fluid.

Fluid inclusions in the S minerals also preserve evidence of a former boiling zone, which may have formed when a former caldera lake drained, causing a rapid decrease in hydrostatic P in the then liquid-dominated system. (From authors' abstract by E.R.)

ELISEEVA, N.A., KOZERENKO, S.V. and **PROKOF'YEV, V.Yu.**, 1988, Boiling of hydrothermal solution and gold precipitation in certain deposits of Northern Kazakhstan: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 22 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci. of U.S.S.R., Moscow, U.S.S.R.

During studies of fluid inclusions in quartz and calcite from two gold deposits (Au-galena-antimonite metasomatic type and Au-telluride quartz-vein type), it was found that the ore-forming solutions had Cl-Mg-Na composition. Solution concentration varied from 14 to 6 wt % NaCl eq., Th from 340 to 190°C. Late solutions were more dilute (5-2 wt %) and cooler (180-50°C). Ore-forming system of the Au-telluride deposit had high P (up to 2.8 kbar) and CO_2 concentrations up to 7 moles per kg of solution, whereas at the Au-galena-antimonite deposits P was from 0.25 to 1.1 kbar and CO_2 2-2.5 moles per kg of solution. Geological data indicate that the first deposit formed at the depth of 7-10 km, but the second one at 2-2.5 km. The studied deposits show typically inclusions with various degrees of filling: essentially gaseous and $CO_2 + H_2O$ ones, indicating boiling of hydrothermal solutions. Presence of scheelite suggests low pH of the environment, but segregation of CO_2 changes the pH values to more alkaline, causing precipitation of Au. (...) (Authors' abstract, translated by A.K.)

ELLISON, A.J.G. and **HESS, P.C.**, 1989, Solution properties of rare earth elements in silicate melts: Inferences from immiscible liquids: Geochim. Cosmochim. Acta, v. 53, p. 1965-1974.

ELMORE, R.D., BAGLEY, D. and LONDON, D., 1989, Timing and origin of the mineralization and alteration association with migration of basinal fluids, Oklahoma (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A260. Authors at School of Geology and Geophysics, The Univ. Oklahoma, Norman, OK 73019.

Paleomagnetic, geochemical, and petrographic data from within and around calcite-filled fractures in the Viola Fm. (Ordovician) in southern Oklahoma constrain the origin of the fluids, the nature of the rock/fluid interactions, and the timing of migration. The fractures are found in a fault zone. Fluid inclusion studies indicate that the calcites precipitated from two basinal fluids. Both were relatively hot (50-90°C) and had high salinities (10-25 eq. wt % NaCl), and one had a high divalent cation content. Oxides and Mississippi Valley Type (MVT) sulfides (e.g., sphalerite) are found in the calcites. Paleomagnetic and petrographic studies of an alteration halo around the fractures indicate that the rock contains a Permian chemical remanent magnetization (CRM) residing in authigenic hematite. The tight limestone away from the fractures contains a Pennsylvanian CRM residing in magnetite.

The results of the study suggest that the basinal fluids migrated up along the fault zone in the Permian and caused the mineralization in the fractures and the remagnetization in the host limestones. Low Tf, low Fe contents of sphalerite, and the absence of galena and Cu-sulfides suggest that the fractures are at the distal (updip, cooler?) edge of a sphalerite-rich MVT deposit near the study area. Mixing of the different fluids (perhaps including meteoric water) and interactions between the fluids and the organic rich Viola probably promoted precipitation of the calcites and oxides/sulfides as well as causing the associated Permian remagnetization. (Authors' abstract)

ELMORE, R.D., LONDON, David, NICK, K. and CATES, K., 1989, Fluid control on chemical remagnetization: The role of meteoric, hydrocarbon, and basinal fluids (abst.): Eos, v. 70, p. 310. Authors at Sch. Geol. and Geophys., The Univ. Oklahoma, Norman, OK 73019.

A key objective in developing a better understanding of chemical remagnetization mechanisms and using a paleomagnetic approach to date diagenetic events, is to relate a specific chemical magnetization to the fluid that caused precipitation of the authigenic magnetic phase. Recent work at Oklahoma has provided evidence for a relation between remagnetization and three different types of fluids. First, a study of hydrocarbon-saturated speleothems in southern Oklahoma suggests a relation between hydrocarbons and a remanence residing in authigenic magnetite. The speleothems, some of which contain hydrocarbons in P fluid-filled inclusions, are Permian in age based on interbedded fossils. Those speleothems which contain hydrocarbons have a Permian magnetization residing in authigenic magnetite which is over an order of magnitude stronger than the magnetization in the speleothems which contain no hydrocarbons. These results suggest that the chemical conditions created by the hydrocarbons caused precipitation of the magnetite and acquisition of the associated chemical remanent magnetization (CRM). Although the mechanism of magnetite authigenesis is poorly understood, several research groups are investigating the problem using geochemical approaches.

(...) In contrast, preliminary results from vein-filling calcites and associated lower Paleozoic carbonates in the Arbuckle Mtns. suggest a relation between basinal fluids and a CRM. FI studies suggest that most of the calcites formed from fluids that had salinities of 10-20 wt % eq. NaCl, high divalent cation content, and were relatively hot (at least 50°C). Oxides (hematite, goethite) and sulfides (sphalerite, marcasite) are also found in the calcites. Paleomagnetic results from limestones in an alteration halo around the veins indicate a late Paleozoic magnetization residing in hematite. Limestones away from the veins contain a magnetization residing in magnetite. Although it is likely there was some mixing with more dilute fluids, the evidence suggests that the basinal fluids caused remagnetization around the veins which were the conduits for fluid flow. (From authors' abstract)

ENJOJI, M., SHIMADA, N., SUGAKI, A. and ALFARO, G., 1989, Zinc-lead mineralization of the Toqui mine, Aysen, Chile (abst.): Min. Geol., v. 39, p. 58 (in Japanese, translated by S. Taguchi). First author at Tsukuba Univ.

Toqui mine, Aysen, Chile, is a Zn-Pb deposit consisting of both vein and strataform type. The latter occurs replacing limestone in Jurassic to Cretaceous submarine volcanic tuffs. Shell parts of fossils in the limestone are replaced by pyrrhotite, sphalerite (FeS = 16-26 mol %), pyrite, and subordinate minerals such as chalcopyrite, galena, and tetrahedrite. Other parts of the fossils are replaced by calcite, quartz, pyrite, sphalerite (FeS = 14-20 mol %), and arsenopyrite. The sphalerite from both parts shows an exsolution structure of pyrrhotite and chalcopyrite.

Fluid inclusions in quartz and calcite are less than 10 μm in size and are usually two-phase. However, CO_2 is often observed in the fluid inclusions in quartz at room T. Th of quartz, calcite and sphalerite are 135-255°C, 140-205°C, and 200-220°C, respectively.

The mineral occurrence and inclusion data suggest that the deposits formed at relatively lower T during rapid changes of precipitating conditions, with several periods of mineralization. (Authors' abstract)

EPSTEIN, D.S., 1989, The Capoeirana Emerald deposit near Nova Era, Minas Geras, Brazil: Gems & Gemology, v. 25, no. 3, p. 150-158. Author at Precious Resources Ltda., Rua Dr. João Antonio, 287, Teófilo Otoni, Minas Gerais, Brazil.

In 1988, a significant find of emeralds was made at Capoeirana, near Nova Era, in the state of Minas Gerais, Brazil. The nature of the biotite schist with which the emerald is associated and the gemological properties of the Capoeirana emeralds indicate that this occurrence is related to the Itabira (Belmont mine) emerald site, only 10 km away. (From author's abstract by E.R.)

Presents a brief discussion of the fluid inclusions illustrated by color photomicrographs. [H.E.B.]

EROKHIN, A.M., GETMANSKAYA, T.I., NAUMOV, V.B. and **CHERNOV, B.S.,** 1989, Genetic peculiarities of formation of cryolite-tin-tungsten mineralization of a new type: Geokhimiya, 1989(3), p. 376-384 (in Russian, English abstract). First author at Vernadskiy Inst. Geochemical and Analytical Chemistry, USSR Academy of Sciences, U.S.S.R.

Based on a study of FI in quartz, cryolite, fluorite and ralstonite, the conditions of formation of the Utulik prospect (SW Cisbaikalia) have been [investigated]. The prospect is located in an ancient block of Precambrian metamorphic rocks and is controlled by deep faults and a dike belt of predominantly acid composition (including ongonites). Formation of these magmatic and post-magmatic rocks occurred at high volatile involvement (H_2O, F, CO_2, CH_4). Ore-formation occurred at 340 to 240°C from high-CO_2 solution with variable content of CH_4 (5 to 10 mol % on average). High fluid P (3.7 to 1.5 kbar), evidencing a connection of the ore zone with deeper parts of the earth crust, is a peculiarity typical of the Utulik ore field. (Authors' abstract) (Name of first author sometimes transliterated as Yerokhin—E.R.)

ERZINGER, J., VON STACKELBERG, U. and **seven others,** 1989, First hydrothermal fluids from a back-arc spreading system (Valu-Fa Ridge, Lau Depression) (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 43 (in German) (supplementary issue to European J. Mineral., v. 1.).

During the French-German cruise to SW Pacific, in the Tonga region, an active ocean floor hydrothermal system was found for the first time in a back-arc spreading ridge, at a depth of 2000 m. Two different solution types were sampled: (1) low-T solution up to 40°C, probably diluted by ocean water and (2) high-T solution up to 342°C. The solutions are very acid (pH 2.5) and contain low amounts of CH_4, Fe and Li, but richer in Ba, Mn, Zn, Cu and B than MOR solutions. The solution composition is probably influenced by the wall andesites and determined by a relatively high H^+ activity. (From the authors' abstract translated by A.K.)

ETHERIDGE, D.M., PEARMAN, G.I. and **de SILVA, F.,** 1988, Atmospheric trace-gas variations as revealed by air trapped in an ice core from Law Dome, Antarctica: Annals of Glaciology, v. 10, p. 28-33. First author at Antarctic Division, Dept. Science, Channel Highway, Kingston, Tasmania 7150, Australia.

A technique for extracting and analysing large air samples from bubbles occluded in an Antarctic ice core is discussed. Core samples of up to 1400 g were milled to release ~120 cm3 of air, which was dried, collected in a cold finger and then analysed by gas chromatography. The concentrations of atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) over the past 450 years have thus been revealed. Measurements of a chlorofluorocarbon (CCl_2F_2) in the ice-core air were used to check core quality and the air-occlusion process.

The ice core, designated BHD, was thermally drilled from the summit of Law Dome, Antarctica, where the average accumulation rate is 0.65 m a^{-1} water eq. and the annual average T is -22°C. Ice dating was achieved by counting annual cycles of oxygen-isotope ratio and d.c. conductivity, and air dating was deduced from the density profile.

The results show the pre-industrial concentrations of the gases to be 288 ± 5 ppm volume for CO_2, 800 ± 500 ppb volume for CH_4, and 285 ± 10 ppb volume for N_2O. (Authors' abstract)

ETMINAN, Hashem, 1989, Biomarkers in fluid inclusions: A new tool in constraining source regimes and its implications for the genesis of Mississippi Valley-type deposits: Geology, v. 17, p. 19-22. Author at Div. Petrology and Geochemistry, Bureau of Mineral Resources, Geology and Geophysics, GPO Box 378, Canberra ACT 2601, Australia.

Biomarkers in FI can constrain source regimes for hydrocarbons associated with Mississippi Valley-type Pb-Zn deposits. Significant amounts of hydrocarbons have been detected in FI in sphalerite and dolomite intimately associated with Pb-Zn sulfides in the Canning Basin, Western Australia. The hydrocarbons are more mature than those in the host rocks to the ore and are therefore derived from an external source. Furthermore, there are differences between the biomarker components of hydrocarbons in I in Pb-Zn prospects, but they are all different from hydrocarbons in organic-rich strata and also in oils from the Canning Basin. Yet, the hydrocarbons are mature and oil-like, suggesting that mature organic-rich strata deeper in the basin, which are less significant as potential source rocks for petroleum generation in the Canning Basin, have contributed to the ore-forming fluids. (From author's abstract)

EVANS, W.C., ROBINSON, S., WHITE, L.D., KLING, G. and **TUTTLE, M.,** 1989, Isotopic studies of Lakes Nyos and Monoun, Cameroon (abst.): Eos, v. 70, p. 1377.

EWERS, G.R. and **SUN S.-S.,** 1989, Genesis of the Red dome gold skarn deposit, northeast Queensland, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: Econ. Geol. Monograph 6, The Economic Geol. Publ. Co., p. 218-232. Authors at Bureau of Mineral Resources, G.P.O. Box 378, Canberra, ACT 2601, Australia.

Some of Australia's most significant Au deposits are associated with late Paleozoic high-level felsic intrusions in northeast Queensland. The Au deposit at Red Dome near Chillagoe is hosted by a complex skarn related to Permo-Carboniferous rhyolites intruded into Siluro-Devonian limestone of the Chillagoe Formation. Native Au and minor electrum are associated with a wollastonite-bearing skarn phase related to an early rhyolite. Au was also deposited during subsequent retrograde alteration and late veining and appears to have been locally reworked with the intrusion of a late rhyolite. Whole-rock geochemistry has indicated that during skarn formation, fluids introduced appreciable amounts of Fe, Mn, Cu, Mo, Sn, Zn, W, and As and leached Na from all lithologies.

FI studies yield P-corrected Th in the range 300° to 380°C for garnet with fluorite forming at 200° to 350°C in the skarns. The fluids have a very low CO_2 content (<0.2 mole %), with salinities of 2 to 24 eq. wt % NaCl in the skarns rising to 30 to 50 eq. wt % NaCl in the rhyolites. Stable isotope data indicate the progressive interaction of a magmatic fluid with the country rocks during skarn formation and suggest a water/rock ratio much greater than 1, probably $\geq$10. Although the O isotope data do not indicate the involvement of meteoric water with low $\delta^{18}O$ values, it is possible that connate or surface water which has been extensively modified by interaction with the sedimentary rocks may have been involved in the later stages of skarn growth, thereby causing a decrease with time in the salinity of the skarn fluids. Sulfur isotope data suggest a mixing of two sulfur sources: a magmatic sulfur and a country-rock source with more positive $\delta^{34}S$ values. (Authors' abstract)

FABRE, D., OKSENGORN, B. and **COUTY, R.,** 1989, Pressure dependence of the Raman scattering cross section of the vibrational band of N_2 (abst.) Symposium GEORAMAN 89, Toulouse, France, 17-19 May 1989, Abstracts (unpaginated). Also in Bull. Liason Soc. Franc. Mineral. Crist., v. 2, no. 1, p. 28 (1990) (in French, English abstract by R. Wilkins, checked by first author). First author at L.I.M.H.P.-C.N.R.S., Université Paris-Nord, avenue J.B. Clément 93430 Villetaneuse, France.

The knowledge of the differential Raman scattering cross sections $d\sigma/d\Omega = \sigma^*$ (for at least one mode of vibration) of species trapped in fluid inclusions in a mineral is necessary if one wishes to use Raman spectroscopy to evaluate their proportions. The values of σ^* are found in the literature for certain molecules of geologic interest; they have been determined for gaseous samples at ~1 bar, whereas the P in inclusions can attain values that are much more elevated.

It is known that σ^* depends on the density σ (or the pressure p) because of molecular interactions and the effect of the internal field. The aim was to evaluate this dependence, starting with the case of N_2. The P can be due to the molecule itself or to other species: the dependence on P will not be the same in these two cases.

In the first stage of this work, we have measured the variations of the scattering cross section of the vibrational band of N2 at ambient T. The Raman experiments were carried out with a back scattering geometry using an optical cell with sapphire windows, the 488 nm line of an Ar ion laser with laser power of ~100 mW, and a triple monochromator. The stability of the diverse mechanical and optical elements of the equipment is the major experimental problem.

The integrated intensity I of the Q-branch of N_2 has been measured as a function of p up to 3 kbar (ρ = ~29 mole/1). [C_n is a calculated corrective factor compensating the p variation of the solid angle of light collection via the p dependence of the N_2 refractive index.]* From the trace of the curves $IC_n/\rho = F(\rho) = K\sigma^*$, the coefficients σ_1/σ_0, σ_2/σ_0, etc. are deduced, and this permits the construction of the curve $\sigma^*/\sigma_0 = f(\rho)$. There is ~6% uncertainty in using the mean curve (Fig. 1) which is described by the equation

$$f(\rho) = \sigma^*/\sigma_0 = 1 + 0.016\,\rho + 4.5\ 10^{-4}\ p^2\ .$$

It is interesting to compare $f(\rho)$ to the curve $L(\rho) = (n^2 + 2)^4/81$ which represents the correction of the internal field. In the absence of specific molecular interactions, $\sigma^* = \sigma_0$ L and the two curves must coincide. In fact, they practically coincide up to almost ρ = 15 mol/l (~500 bar). For higher P the measured cross section grows more quickly than the internal field correction. The gap between the two curves represents the influence of molecular interactions, and appreciable variation is possible in the case of gas mixtures. (Authors' abstract)

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*This definition added by Mme Fabre to the printed abstract. (E.R.)

FABRICIUS, J., 1989, Fluid inclusions with daughter bischofite, $MgCl_2 \bullet 6H_2O$, in recrystallized halite from Zechstein 2 rock salt, Denmark (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 30. Author at Geol. Survey Denmark, Thoravej 8, DK 2400, Copenhagen NV, Denmark.

Large irregular FI with daughter bischofite, $MgCl_2 \bullet 6H_2O$, in recrystallized halite from a former brine pocket in grey Zechstein 2 rock salt from the Suldrup dome, Denmark, were studied by means of microthermometry.

The test material consists of extremely clean, colorless, limpid halite. The solid inclusions, anhydrite and pyrrhotite, are present as traces only. The studied irregular inclusions all contain dm bischofite at room T.

The mean dissolution T, Tm hex = 55.8 ± 1.2°C (95% confidence limit, of 68 measurements) gives from appropriate phase diagrams a quantitative composition of the equilibrium solution: 114 mol $MgCl_2$ + 1.2 mol K_2Cl_2 per 1000 mol H_2O, saturated with NaCl (c. 2 mol Na_2Cl_2 per 1000 mol H_2O). Exposed to the atmosphere, the equilibrium solution becomes yellowish during a couple of days, proving the presence of $FeCl_2$ (5-10 moles per 1000 H_2O). In one inclusion, dm carnallite ($KMgCl_3 \bullet 6H_2O$) was observed; the dissolution T of which Tm car = 81.0°C is a minimum Tt. The minimum Pt is calculated to be slightly higher than 65 MPa. Measurements of the Th into the fluid phase are meaningless due to the presence of compressed H_2S gas.

The following model is proposed concerning the formation of the studied halite: During the end of the Lower Cretaceous diapiric penetration phase, a metamorphic lye[sic] mixed with concentrated sea water in halite facies in a brine pocket within the grey Zechstein 2 rock salt, causing salting out of the studied halite. The metamorphic lye is presumed to have been derived from a metamorphosed carnallitic potash zone. The carnallitic solution then mixed with an infiltrating rinneitic ($3KCl.NaCl.FeCl_2$) solution. The mixture was subsequently squeezed out fro the potash zone during the diapiric penetration phase, leaving a trail of disseminated grains and fracture fillings of carnallite all the way up to the studied former brine pocket. (Author's abstract)

FABRIÉS, Jacques, BODINIER, J-L., DUPUY, Claude, LORAND, J-P. and **BENKERROU, Constance**, 1989, Evidence for modal metasomatism in the orogenic spinel lherzolite body from Caussou (northeastern Pyrenees, France): J. Petrol., v. 30, part 1, p. 199-228. First author at Laboratoire de Minéralogie, Muséum Nat'l d'Histoire Naturelle, C.N.R.S. U.A. 286, 61 rue Tuffon, 75005 Paris, France.

Metasomatic mineral-bearing and/or trace element-enriched ultramafic assemblages have been reported from very few Alpine-type massifs. The small ultramafic body from Caussou (Ariège, northeastern Pyrenees) shows distinctive features which are similar to those of modally metasomatized mantle xenoliths found in alkali basalts. In the last stage of the metasomatism, segregation of more fractionated silicate liquids, coexisting with a (CO_2 +H_2O) fluid phase, may have been responsible for the crystallization of titanian pargasite, possibly by means of hydro-fracturing mechanism. (From authors' abstract by E.R.)

S CO_2 inclusions in amphibole peridotite had Tm CO_2 -56.6 to -57.5°C. All had Th L-V (L) between -9.4 and +2.9°C, corresponding to densities of 0.98-0.92 g·cm^{-3}. (E.R.)

FAHLQUIST, L.S. and **POPP, R.K.**, 1989, The effect of NaCl on bunsenite solubility and Ni-complexing in supercritical aqueous fluids: Geochim. Cosmochim. Acta, v. 53, p. 989-995. First author at Mail Stop 910, U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94015, USA.

Experiments were carried out using rapid-quench hydrothermal techniques to determine the solubility of bunsenite (NiO) in supercritical H_2O-NaCl-$NiCl_2$ solutions in the range 550 to 750°C, at 2 kbar. The solubility of NiO was enhanced by the formation of complexes of higher stoichiometry than $NiCl_2^0$ in the presence of increasing concentrations of aqueous NaCl. The results are consistent with the formation of the $NiCl_3^-$ complex in the fluid over the entire T range.

Despite the increase in solubility that results in the NaCl-bearing system, nickel should still remain a relatively immobile element, as compared to Ca, Mg, Fe and Mn, in supercritical aqueous Cl-bearing fluids, provided the activity of nickel in the coexisting solid mineral assemblage is not unusually high. (From authors' abstract by E.R.)

FAIZIEV, A.R. and **ISKANDAROV, F.Sh.**, 1989, To diagnostics of the primary and secondary fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 23. Authors at Tadjik State Univ., Dushanbe, 734016, USSR.

The determination of primariness-secondariness of FI is the decisive moment in the interpretation of thermobaric investigation results.

As it is known, the most important criterion of the primariness of inclusions is their confining to the growth forms of the crystals, and the inclusions are regarded to be the S ones, if they intersect all crystal growth elements and usually are located in the fissures, healed at the later stages of the mineral formation. The P inclusions are distributed more or less regularly inside the mineral, but the S ones are developed only in the planes of the healing fissures. The P inclusions are mostly the three-dimensional ones and often have the form of negative crystals. In contrast, the form of the S inclusions is irregular and flat as a consequence of their location in thin fissures.

Using the noted criteria it is possible comparatively easily to determine the primariness or secondariness of inclusions, when the mineral occur in the form of crystals. But the determination of P and S inclusions in polycrystalline aggregates isn't always the easy problem. In particular, in the non-oriented cuts of crystals and thin sections there are no reliable criteria of distinguishing between the growth zone inclusions and vacuoles in the healing fissures: either can be oriented linearly along the distinct direction. We obtained the data, allowed to solve this problem.

Our studies of fluorite, quartz, calcite and barite crystals from the different ore deposits in the Tadjikistan show, that the P inclusions are oriented perpendicular to the growth zones of the former faces of crystals and are represented to be the systems of cavities, parallel each to other along the elongation (Fig. 1). The orientation of the S inclusions is different. So far as the fissure healing is proceeding by the way of dendritic overgrowthing, the elongations of the S inclusions are oriented along the fissures (Fig. 2). Thus, if in non-directed preparates of minerals the inclusions are characterized by the parallel orientation of their elongations, then such vacuoles ought to be considered as the P ones, and on the contrary, when inclusions are characterized by the chain arrangement, then they are regarded as the S ones.[sic] (Authors' abstract)

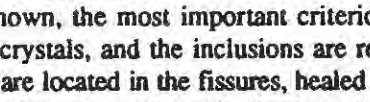

Fig.1

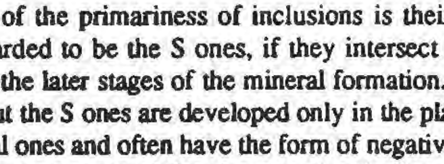

Fig.2

FANG, Genbao, LU, H.-Z. and GUHA, Jayanta, 1989, Linglong, an intrusive hosted gold deposit, Shandong Province, China - Fluid characteristics (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 24. Authors at Inst. Geochem., Acad. Sinica, Guiyang, PRC.

The Linglong area in Shandong Province is one of the largest and most famous Au camps in China. The Linglong granite, hosting most of the dozen Au mines, is a part of the Eastern Shandong Precambrian Shield. The country rocks are Archaean biotite granulites, plagioclase hornblendites and amphibolitic granulites which form a complex northwest trending anticlinorium. The intrusive is a composite body consisting of medium to coarse grained granite, gneissic biotite-granite, garnet-bearing leucogranite and K-spar-bearing gneissic granodiorite. The major structures in the area of the Linglong Au mine are a northeast-trending shear zone and minor faults related to the shearing, controlling the emplacement of the mineralization. The immediate host rocks are gneissic biotite granite and K-spar-bearing gneissic granodiorite. The deposit is divided into two zones, East and West, showing slightly differing geometry. The East zone mineralization consists of fault controlled stockwork type veins whereas the West zone is mainly large veins enclosed within shear zones. The mineralization's characteristics in both the mines are similar. Four stages have been recognized: milky quartz-pyrite, Au-quartz-pyrite, Au-base metal sulfides-quartz, and carbonate veins. The ore minerals are native Au and electrum associated with pyrite and chalcopyrite. The alteration associated with the mineralization is mainly silicification and sericitization which are superimposed on the metamorphic mineral assemblage of the granitic rocks.

A combination of H_2O-rich (3-17 wt. % eq. NaCl), CO_2-H_2O, and CO_2-CH_4 inclusions present in the four stages of vein formation indicate an evolutionary trend of the ore mineralizing fluid. Two dominant phases are apparent, one a NaCl-H_2O system and the other a CO_2-H_2O-CH_4 system. Th range from 200° to 380°C, for both systems. This may best be explained by unmixing of the two systems from a single phase. However, a few oxygen and hydrogen isotope analyses of fluids from stage 1 and 2 veins indicate meteoric water mixing, driving the composition (+2‰) towards negative oxygen values during the second stage (-2‰). The presence of a CO_2-dominated system could be interpreted as a deeper fluid of magmatic or metamorphic origin. However, overprinting of the metamorphic assemblage by the alteration associated with the mineralization puts some constraint on a metamorphic input. Although more isotopic data is needed to outline a definite signature of magmatic fluids, the Linglong deposit seems to have been emplaced in a shallow level, post-dating the granulitization of the intrusive. (Authors' abstract)

FARMER, C.B., 1989, The importance of cathodoluminescence techniques in the thermometric study of fluid inclusions in hydrothermal ore deposits (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 31. Author at Dept. Geol., Imperial College, London, UK.

(...) In polyphase deposits cathodoluminescence studies are a fundamental stage in the interpretation of FI data. Observations have been made from two deposits, South Crofty Mine, Cornwall, UK, and Patchway Mine, Zimbabwe. The Sn mineralization at South Crofty occurs in the form of cassiterite in several stages of the paragenesis which includes the gangue mineralization of quartz, tourmaline, chlorite and fluorite. The paragenesis is controlled by an evolving sinistral shear gangue mineralogy under cathodoluminescence. Cassiterite, quartz and fluorite exhibit luminescence which is correlated with microthermometric data. Data collected shows a range of Th measurements from 110°C to >475°C and salinity from <1 to 30 wt % NaCl eq. In some cases eutectic melting indicated the presence of $CaCl_2$ brines. Small amounts of CO_2-rich, low salinity, high Th inclusions are found in association with wolframite mineralization. This data is consistent with other work in the metalliferous region of S.W. England. In Patchway Mine, the Au mineralization is developed within an evolving shear zone. Of the gangue mineralization, FI studies have been made in quartz which shows luminescence relationships which provide a stricter control on the data for the Au mineralization stage of the quartz paragenesis. Au-bearing quartz has coexisting CO_2-rich and CO_2-poor inclusions of low salinity (2 to 5 wt % NaCl eq.) with a Th range of 250°C to 300°C. Later quartz has higher salinity inclusions (5 to 10 wt % NaCl eq.) with a lower Th range to 100°C to 150°C, this population is also present as S inclusion trails in the Au-bearing quartz.

The critical importance of cathodoluminescence studies are that they provide a quick, nondestructive method of defining a microscopic paragenesis not visible in transmitted light microscopy or by use of the SEM. In future it is hoped that the wavelength of light emitted from discrete quartz generations will provide a data base to allow correlations between different structures within the same deposit. (...) (From author's abstract by E.R.)

FAROOQ, S. and PANT, I.D., 1989, A rapid economical method for preparation of polished sections: Indian J. Earth Sci., v. 16(1), p. 6-71.

FARVER, J.R. and GILETTI, B.J., 1989, Oxygen and strontium diffusion kinetics in apatite and potential applications to thermal history determinations. Geochim. Cosmochim. Acta, v. 53, p. 1621-1631. Authors at Dept. Geological Sciences, Brown Univ., Providence, RI 02912.

The kinetics of O and Sr diffusion in natural fluorapatite (Durango, Mexico) have been measured under hydrothermal conditions using an ion microprobe. Diffusion coefficients were obtained at 550 to 1200°C for O, and 650 to 1200°C for Sr. All experiments were run at 1000 bars (10 MPa) water P except those designed to measure the water P dependence, which were at 200 to 2000 bars.

The diffusion coefficient for O transport parallel to the *c* axis is approximately three orders of magnitude greater than that perpendicular to the *c* axis over the T range of the experiments. No anisotropy was observed for Sr diffusion in apatite. An increase in water P from 200 to 2000 bars yields an increase in *D* of approximately a factor of three for O diffusion parallel to the *c* axis at 800°C.

The new data show that closure T calculated for Sr diffusion in apatite are significantly lower than the high-T studies would predict. Thus, apatite crystals would remain open to Sr diffusion exchange well below the solidus T of most igneous rocks. This could result in higher $^{87}Sr/^{86}Sr$ values in the apatite than the whole-rock initial value. Measurable enrichment in $^{87}Sr/^{86}Sr$ values in apatite could also be produced by a later thermal disturbance at moderate geologic T and durations. (From authors' abstract by E.R.)

FARVER, J.R. and YUND, R.A., 1989, The effect of H_2, O_2, and H_2O fugacities on oxygen diffusion in alkali feldspar (abst.): Eos, v. 70, p. 501.

FEDOROWICH, J.S., 1989, Structural controls and fluid character of the Proterozoic Tartan Lake gold deposit, northern Manitoba (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-3. Author at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

Sinstral transcurrent shear zones formed by compressional deformation of the Flin Flon Domain during the Trans-Hudson Orogen. Au mineralization occurs in some of these structures, one example of which is the Tartan Lake Au deposit, 12 km northeast of Flin Flon, Manitoba.

Mineralized shear zones at Tartan Lake are developed in metabasalts and metagabbros, as a 0.3 km wide transpressional set, on part of an extensive regional structure that cross-cuts earlier formed folds. Within this set, individually mapped shears vary in width from 5-35 m, and vary in composition inward from their margins. They exhibit a progressive decrease in chlorite, epidote, and actinolite, and an increase in sericite, carbonate, quartz, pyrite, and tourmaline, in response to increased hydrothermal alteration.

Deformation within the shear zones is displayed by the following features: development of S and C schistosities; folding of the schistosities; cleavage axial planar to these folds; concomitant kink banding; and, in the rocks immediately adjacent to the shear zone, a well-developed cleavage structure.

A systematic sequence of veins is characterized by distinctive orientations and mineral paragenesis, and provides a record of changing conditions during progressive deformation. Earliest quartz carbonate veins are barren and folded along with schistosity. Intermediate stage quartz-carbonate-tourmaline veins trend sub-parallel to the shear zone C-surfaces, and host high grade Au mineralization. An array of vertical veins cut all of the above as tensile features parallel to maximum compressive stress. Finally, late sub-horizontal carbonate-quartz veins, and partially filled fractures with small displacements are evidence for latest fault activity at decreased confining P.

Au mineralization occurred with the intermediate, and array stages of veining, bracketed by two barren vein events. Results from a study of FI indicate that mineralization formed from aqueous, low-salinity (2-7 wt % NaCl eq.) fluids with CO_2 contents of 3 to 24 mol %, and Th of 250 to 300°C. (Author's abstract)

FEELY, M., 1989, Fluid inclusion studies of a potash-feldspar breccia in the Galway Granite, west of Ireland (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 32. Author at Dept. Geol., University College, Galway, Ireland.

The Galway Granite is a late-Caledonian 'I-type' intrusion emplaced at 400 Ma. (...) The batholith hosts a variety of sulphides (molybdenite, chalcopyrite, pyrite, galena and sphalerite) that are commonly associated with late quartz veins and joints. Disseminations within aplites and pegmatites and within the various granites are also present. Significant concentrations of molybdenite occur at two localities within the Carna Dome at the western end of the batholith (i.e., Mace Head and Murvey). At Mace Head, in the center of the Dome, a NE trending zone (3 km long and 1 km wide) contains Mo-Cu concentrations (0.05% - 0.15% each). Chalcopyrite and pyrite are disseminated while the Mo occurs in a quartz vein stockwork. Spatially associated with this zone occurs a potash-feldspar breccias. This is of the general type associated worldwide with Mo and other metal concentrations in granites. This particular breccia, is cut by Mo-bearing quartz veins, is clast supported and is composed of sub-angular fragments of K-feldspar (<10 cm) and granite (<25 m) set in a matrix of quartz (<1 cm) biotite (<5 cm) and apatite (<3 mm).

Studies of the FI hosted by the matrix quartz have revealed that they are liquid-rich two-phase (L + V) inclusions whose size ranges between 5-15 μm. Smaller inclusions delineate fractures within the quartz. Inclusion morphology varies between spheroidal and oblate shapes—some negative crystal forms have been observed. Thermometric analysis reveals a wide range of Th values (125-400°C) with the majority between 250-350°C. Salinities are generally <10 wt % NaCl eq. Comparisons will be made between this data and that from breccias associated with other Mo stockwork deposits. (From author's abstract by E.R.)

FEIN, J.B. and **HEMLEY, J.J.**, 1989, Experimental study of Fe-Cl complexing in hydrothermal fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A103.

FELDMAN, M.D. and **KNAUTH, L.P.**, 1989, The oxygen content of the Permian atmosphere: Results from direct measurement of paleoatmospheric gases dissolved in brine inclusions in halite (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A138. Authors at Dept. Geology, Arizona State Univ., Tempe, AZ 85287.

The N_2, O_2, and Ar contents of 30 samples of Permian bedded halite from the Palo Duro Basin, Texas, have been measured by manometric and mass spectrometric techniques. The Ar content of the halite ranges from <0.1 to 7.5 cm^3 (STP) of trapped Ar per kg of salt, with most of the data lying between 0.5 and 5 cm^3 (STP)/kg. The $^{40}Ar/^{36}Ar$ and bulk K content of the salt suggests that radiogenic Ar accounts for less than 10-15% of the total Ar. The Ar content of the salt matches values calculated from the solubility of atmospheric Ar in evaporite brines and the H_2O content of the salt, indicating that the trapped gases are dissolved in brine inclusions. Both petrographic and stable isotopic data suggest that the brine inclusions contain well-preserved Permian evaporite fluids; the trapped gases apparently represent gas dissolved in shallow Permian-age brine pools.

The N_2/Ar ratios of the trapped gases are considerably elevated relative to modern air. Both high N2 contents and low CO_2/N_2 ratios are compatible with the presence of large amounts of biogenic N2 produced by denitrifying bacteria in the brine pools.

The O_2/Ar ratios of the trapped gases fall into two groups. Most of the samples have O_2/Ar ratios between 1 and 25, while clay-rich samples have $O_2/Ar > 35$. The high O_2/Ar ratios of the clay-rich salts are due to contamination by fractionated modern air associated with the clastics. The salts with O_2/Ar ratios between 1 and 25 appear to contain uncontaminated Permian-age dissolved atmospheric gases. We suggest that the salts with the highest O_2/Ar ratios crystallized from brines saturated with respect to Permian air. The low O_2/Ar ratios of some salts may be a consequence of diagenetic oxygen consumption, or may be due to anoxic conditions during halite deposition in the Permian brine pools.

Assuming that the Ar content of the atmosphere has not changed appreciably over the last 250 m.y., our O_2/Ar data are compatible with a *minimum* oxygen content for the Permian atmosphere identical to or slightly higher than that of modern air. The upper bound on Permian atmospheric pO_2 provided by the data is approximately twice the modern value. The upper limit requires geological and chemical depositional conditions that are less realistic than the lower bound. The simplest interpretation of our data is that the oxygen content of the Permian atmosphere was approximately equal to or slightly greater than modern air. (Authors' abstract)

FENG, Zhiwen, XIA, Weihua, ZHANG, Jintong and CHEN, Ziying, 1989, Geological characteristics of the Huangsha vein-type tungsten deposit and a discussion on the property of its ore-forming fluid, Jiangxi: J. Wuhan College of Geology, v. 14(4), p. 423-432 (in Chinese).

FENG, Zhongyan, 1989, Genesis of iron skarn deposits in Southern Taihang Mountains, China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-480. Author at Beijing Univ., Beijing, P.R.C.

Southern Taihang Mountains is a famous metallogenic province of iron skarn deposits in China. More than 60 iron skarn deposits have been well explored, and the commercial value of these deposits is very large.

Garnet-pyroxene stage: Estimates of T, P, and fluid composition during garnet-pyroxene stage: T, 600-400°C; P, 300-500 bars; salinity, 50-60 wt % eq. NaCl; isotopic estimates source of hydrothermal fluid, magmatic.

Quartz-iron oxides stage: The period of iron oxides deposition follows the cessation of garnet-pyroxene skarn growth and is accompanied by the beginning of hydrous alteration of early skarn minerals. The predominant minerals of this stage are hematite, magnetite, epidote, and quartz. Estimates of T of this stage are 500-380°C; P, 300-500 bars; salinity, around 40 wt % eq. NaCl; isotopic estimates source of hydrothermal fluid, magmatic.

Quartz-sulfides stage: Sulfides always deposit after oxides deposition. The mineral assemblage of this stage consists of chlorite, tremolite, serpentine, talc, calcite, quartz, pyrite, chalcopyrite, etc. Estimates of T, 350-150°C; P, 300-500 bars; isotopic estimates source of fluid, magmatic mixed with meteoric. (From authors' abstract by E.R.)

FERRY, J.M., 1989, Fluid flow, mineral reactions, and metasomatism: A general model (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A83.

FISHER, N.I., 1989, Smoothing a sample of circular data: J. Struct. Geol., v. 11, no. 6, p. 775-778.

The paper discusses certain pitfalls in the presentation of sample data sets, that are particularly appropriate in the plotting of Th histograms. An example (Figure 1) shows two histograms of the same 105 data points. Figures 1a and 1b have the same *bin width* (20) and *bin boundaries* (0-20, 20-40, etc.), but the data set in Figure 1b has been shifted *en masse* by adding 25 to each datum. Note how the apparent bimodal distribution inferred from 1a disappears in 1b. The (normally arbitrary) location of the bins *with respect to the data* can be of major import. The author proposes an alternative plotting procedure, a "non-parametric density estimate," which is a method of smoothing data to avoid the arbitrary choice of cell boundary; some subjectivity is involved, however, to avoid "undersmoothing" and "oversmoothing." (E.R.)

FISHER, R.S., POSEY, H.H. and KYLE, J.R., 1989, Successive pore fluid generations in a Lower Permian brine aquifer, Palo Duro Basin, Texas Panhandle, U.S.A.: Applied Geochem., v. 4, p. 455-464. First author at Bureau of Economic Geology.

The successive presence of four compositionally distinct pore fluids in Lower Permian carbonate strata of the Palo Duro Basin, Texas Panhandle, is interpreted from (1) lithological, mineralogical, and petrographic evidence for depositional conditions; (2) isotopic compositions of C, O, and Sr in limestone and dolomite; (3) limited data on fluid inclusions in sphalerite; and (4) chemical and isotopic analyses of formation water. (From authors' abstract by E.R.)

FLEET, M.E., 1989, Sulfide-silicate equilibria and Ni-Cu sulfide deposits (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-95.

FOLEY, N.K. BETHKE, P.M. and RYE, R.O., 1989, A reinterpretation of the δDH_2O of inclusion fluids in contemporaneous quartz and sphalerite, Creede mining district, Colorado: A generic problem for shallow orebodies?: Econ. Geol., v. 84, p. 1966-1977. First author at U.S. Geol. Survey, 959 Nat'l Center, Reston, VA 22092.

Water extracted from fluid inclusions in quartz from shallow epithermal ore deposits often has a hydrogen isotope composition (δD) different from that of water extracted from inclusions in associated minerals. This difference is usually attributed to the involvement of P fluids from multiple sources. Isotopic and Th and Tm ice determinations on fluid inclusions from contemporaneous quartz and sphalerite from the epithermal, Ag and base metal orebodies of the OH vein, Creede district, Colorado, suggest an alternative explanation. In near-surface deposits, differences between δDH_2O of inclusion fluids in ore minerals and quartz may result, instead, from contamination during extraction of the fluids contained in P inclusions by shallow ground water trapped in PS inclusions in quartz.

Quartz from the OH vein contains two principal petrographically distinct populations of fluid inclusions: P and PS. The P inclusions have salinities ranging from 5 to 10 eq. wt % NaCl, and the salinities of PS inclusions cluster between 0 and 1%. P inclusions in quartz from one locality have a measured δDH_2O value of -69‰, while PS inclusions at the same locality have a δDH_2O value of -102‰. Both salinity and isotopic values for P inclusions in quartz are similar to those for P inclusions in contemporaneous sphalerite. Th for P and PS inclusions in quartz range from 191° to 280°C and from 199° to 278°C, respectively. The δDH_2O value measured on fluid inclusions from bulk crystals ranges between -97 and -85‰ and represents a mixture of fluids from both P and PS inclusions.

We interpret the data to indicate that one or more episodes of abrupt incursion of cooler, overlying ground water into the ore zone caused thermal cracking of the quartz crystals during the time interval of mineralization. Subsequent healing of the fractures trapped heated, low-salinity ground water in PS inclusions. The abrupt incursions of overlying ground water are speculated to have resulted from either collapse of a transient vapor-dominated region of the ore zone, or catastrophic venting of the system through hydrothermal eruption(s).

The unusually high contrast between the salinities of the ore-depositing fluids and the ground water overlying the ore zone allowed recognition of this phenomenon at Creede. It is likely, however, that Creede is not unique. Similar phenomena may be common in shallow ore zones where rapid fluctuation of an interface between a deep, high-T thermal plume and an overlying, cooler ground water may be expected to occur. Careful study of the origins of fluid inclusions, particularly in quartz, is essential to characterize the primary ore fluids and to assess the role of ground water in the hydrology of shallow ore deposits. (Authors' abstract)

FOLK, R.L., 1989, Internal structuring of quartz as revealed by boiling concentrated hydrofluoric acid: J. Geol. Education, v. 37, p. 250-260. Author at Geosciences Dept., Univ. Texas at Austin, Austin, TX 78712.

Quartz, when etched in boiling concentrated hydrofluoric acid, shows a great variety of internal structures. Many clear quartz crystals etch into slots and partitions that are parallel to the *c* axis and perpendicular to prism faces. Other quartz crystals show splays of etch tubes converging to a point. Granitic quartz develops minute strands parallel to the *c* axis, whereas volcanic quartz forms a very smooth surface. Metaquartzites show minute fractures and occasional coils of insoluble inclusions. Quartz overgrowths are etched much more than the mother grains. I suggest that differential etching is caused by aluminum impurities and/or lattice distortion in the quartz crystal lattice. (Author's abstract)

Of pertinence to the possible trapping of inclusions in etch tubes. (E.R.)

FONTEILLES, Michel, SOLER, Pierre, DEMANGE, Michel, DERRÉ, Colette, KRIER-SCHELLEN, A.D., VERKAEREN, Jean, GUY, Bernard and ZAHM, Alain, 1989, The scheelite skarn deposit of Salau (Ariege, French Pyrenees): Econ. Geol., v. 84, p. 1172-1209. Centre National de la Recherche Scientifique, Petrologie (Eruptive et Métamorphique), Magmatologie et Métallogénie, Univ. Pierre et Marie Curie, 4 place Jussieu, 75005 Paris, France.

The skarn deposit is hosted in a Devonian carbonate and partly detrital series intruded by a late Carboniferous stock. The Hercynian orogeny involved polyphase deformation, regional metamorphism of greenschist facies, and late intrusions of granite-granodiorite. Deformation included two coaxial stages of tight isoclinal folding and one important later stage which partly controlled the intrusion of the granodiorite stock, followed by three stages of brittle deformation. Ore deposition is related to faulting stages 0 and 1 and orebodies are cut into slices by stage 2 reverse faults.

After isochemical contact metamorphism, the skarns and ores developed in two main stages related to the infiltration of two quite different types of fluids. During the first stage (540°-450°C), anhydrous skarn formation was followed by an intergranular development of pyrrhotite-scheelite-quartz-calcite in equilibrium with the earlier hedenbergite. The resulting W grade is uneconomic. The associated fluids, probably of magmatic origin, had a high salinity. In the second stage (450°-350°C), no new skarn formed; transformations of the silicate rocks are observed. A first substage of epidotization was followed by the development of intermediate grossularite-almandine-spessartite garnet and finally by the main ore stage with scheelite, pyrrhotite, arsenopyrite, and other sulfides with some Au. Two types of fluid inclusions are found in this stage; one is similar in composition to the first stage, the other is characterized by low salinity and high CO_2 and CH_4 contents. (From authors' abstract by E.R.)

FONTES, J-C., FRITZ, Peter, LOUVAT, Didier and **MICHELOT, J-L.,** 1989, Aqueous sulphates from the Stripa groundwater system: Geochim. Cosmochim. Acta, v. 53, p. 1783-1789. First author at Laboratoire d'Hydrologie et de Géochemie Isotopique, Univ. Paris-Sud, F-91405 Orsay, France.

The isotopic composition of aqueous sulphate in the groundwater in the Stripa pluton reflects the geochemical history of the groundwater as well as the origin of the sulphur or sulphate. In shallow, modern groundwater, sulphate originates from fallout and the oxidation of pyrite or other reduced forms of sulphur. At intermediate depths, sulphate of surface origin is lost through bacterial reduction. The origin of sulphate of the deep and more saline water is not clearly defined but could be derived from a sedimentary brine which was subject to substantial modification through rock-water interaction. Bacterial sulphate reduction also occurs locally at depths below ~800 m. (Authors' abstract)

FORBES, P.L., MEYER, A. and **PAGEL, M.,** 1989, Modeling of apatite fission tracks formation and annealing: Applications to thermal evolution in the Guezouman formation at Akouta, Nigeria (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-499-500.

FORTIER, S.M. and **GILETTI, B.J.,** 1989, An empirical model for predicting diffusion coefficients in silicate minerals: Science, v. 245, p. 1481-1484.

An empirical model describing the diffusion kinetics of oxygen in silicate minerals under hydrothermal conditions has been established for T between 773 and 1073 Kelvin at 100 megapascals of water P. The equation, $\log D = \alpha + (\beta/T) + [(\gamma + (\delta/T))Z]$, where D is the diffusion coefficient, α, β, γ, and δ are constants, T is the Kelvin T, and Z is the total ionic porosity, may be used to predict diffusion coefficients, in most cases to within the reported experimental reproducibility of a factor of 2. For oxygen diffusion, $\alpha = -2$, $\beta = -3.4 \times 10^4$ K, $\gamma = -0.13$, and $\delta = 6.4 \times 10^2$ K, for D in square centimeters per second. Limited data for the diffusion of argon in silicates suggest that the model describes this system as well. (Authors' abstract)

FOURNIER, R.O., 1989, Geochemistry and dynamics of the Yellowstone National Park hydrothermal system: Ann. Rev. Earth Planet. Sci., v. 17, p. 13-53.

An extensive review (with 83 references) of the present state of knowledge of the physics and chemistry of this huge hydrothermal system, including boiling phase assemblages, fluid-rock interactions, enthalpy/chloride relationships, dissolved gases, meteoric recharge, magmatic components, etc. (E.R.)

FOURNIER, R.O. and **KENNEDY, B.M.,** 1989, $^3He/^4He$ as a guide to gold transport and deposition in thermal waters at Yellowstone National Park, Wyoming (abst.): Eos, v. 70, p. 1378.

In thermal waters with near-neutral pH, Au is probably transported mainly as a bisulfide complex that is stabilized by high activities of H_2S. Dissolved Au precipitates where H_2S decreases as a result of boiling or dilution by H_2S-poor fluids. At Yellowstone, deeply circulating meteoric water attains a maximum T of ~350-430°C and picks up dissolved constituents from the surrounding rock and from fluids released by crystallizing magma. Heated water containing H_2S and Au convects upward and, to various degrees in different regions, boils and (or) mixes with shallow fluids of local meteoric origin. Enthalpy-chloride relations and chloride-bicarbonate ratios can be used as a guide to the degree of boiling and mixing that may have occurred. There is ambiguity, however, because a fluid that has undergone conductive cooling, with only minor loss of H_2S by chemical reactions, may plot at the same position on an enthalpy-chloride diagram as a fluid that has undergone a considerable amount of boiling plus dilution that result in a major decrease in H_2S concentration. It is difficult to make a direct determination of H_2S carried to the surface in boiling springs because of near-surface oxidation and uncertainties in the mass ratio of discharged steam to water. The $^3He/4He$ ratio (R) in thermal water offers a means of getting around these difficulties. At Yellowstone, R ranges from

2.7 to 16 times the ratio in air (Ra), reflecting a mixture of magmatic He tagged by ^{3}He and radiogenic ^{4}He derived from aquifer rocks. A model has been proposed suggesting that high R/Ra values in surface springs indicate little or no loss of ^{3}He and other gases from ascending thermal water by boiling and separation of steam deep in the system. High R/Ra values, therefore, should be accompanied by relatively high partial P of CO_2 and H_2S. Preliminary results for 13 samples from eight springs suggest that sinters deposited from waters in regions where R/Ra < 9 have two to three orders of magnitude more Au than sinters deposited from waters with relatively low R/Ra. Where little Au is contained in sinter deposited at the surface at Yellowstone, and where R/Ra < 9, it is likely that Au is being deposited at lower levels underground as a result of boiling and mixing. (Authors' abstract)

FOURNIER, R.O., TRUESDELL, A.H. and **TRUESDELL, A.H.**, 1989, Hydrogeologic model to account for variations in ^{3}He/^{4}He in thermal waters throughout Yellowstone National Park, Wyoming (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-506.

FOWLER, A.D., STANLEY, H.E. and **DACCORD, Gérard,** 1989, Disequilibrium silicate mineral textures: Fractal and non-fractal features: Nature, v. 341, p. 134-138. First author at Ottawa-Carleton Geoscience Centre, Univ. Ottawa, Ottawa, Ontario K1N 6N5, Canada.

Igneous rocks formed from lava flows of the Archaean era (>2,700 million years ago) are often found to contain disequilibrium-textured crystals characterized by spherulitic, branching or dendritic morphologies that occur in layers near the flow surface. Well-known examples are the plagioclase spherulites of basalts and the platy and branching spinnifex-textured olivines and pyroxenes of komatiites. Here we present evidence that, over a finite range of length scales, some disequilibrium textures are scale invariant. This observation implies that over this range of length scales, their random patterns can be quantitatively characterized by a unique number, the fractal dimension. We also demonstrate that some textures have a crossover from fractal to non-fractal behaviour. It is known that most disequilibrium crystals arise in part from rapid cooling and represent the case where the growth rates of the crystals are large compared to the diffusion rates in the silicate melt. We therefore formulate a quantitative model for the growth that is based on a variant of diffusion-limited aggregation (DLA). (Authors' abstract)

FÖRSTER, H.-J., THOMAS, R. and **TISCHENDORF, G.,** 1989, Physicochemical conditions as controlling factors on magmatism and metallogenesis, *in* G. Tischendorf, ed., Silicic Magmatism and Metallogenesis of the Erzgebirge: Central Inst. for Physics of the Earth, VEB Geological Research and Exploration Freiberg, Potsdam, no. 107, p. 221-242.

An extensive review of fluid inclusion literature on Sn-W (and other) deposits of the Erzgebirge (e.g., 11 papers by R. Thomas and coauthors) and including a plot (p. 236) relating Th to the age of mineralization (from 300 to 100 m.y.). (E.R.)

FÖRSTER, H.-J. and **TISCHENDORF, G.,** 1989, Reconstruction of the volatile characteristics of granitoidic magmas and hydrothermal solutions on the basis of dark micas: The Hercynian postkinematic granites and associated high-temperature mineralizations of the Erzgebirge (G.D.R.) 1. Communication: Calculation procedure and results: Chem. Erde, v. 48, p. 7-20.

Applying existing numerical and graphical approaches providing the link between trioctahedral mica composition and fluid chemistry several volatile data have been calculated, and are expressed in terms of fO_2, fHF/fH_2O, fHF, $fHCl/fH_2O$, fHCl, and fHF/fHCl during igneous mica formation from the ore-generating granites of the Hercynian postkinematic Older (OIC) and Younger Intrusive Complex (YIC). (From authors' abstract by E.R.)

FRANTZ, J.D., HICKMOTT, D.D., ZHANG, Y.G. and HOERING, T.C., 1989, Techniques for experimentally loading and analyzing gases and their application to synthetic fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 25. Authors at Geophys. Lab., 2801 Upton St., N.W., Washington, DC 20008.

Experimental studies involving mixed-volatile fluids have long been a research focus for many experimentalists working under hydrothermal conditions. Of particular interest are experimental studies of the properties of hydrothermal fluids using synthetic FI. One of the principal difficulties in investigating mixed volatile reactions under hydrothermal conditions has been in loading the experimental charges with gas mixtures of known composition. A technique has been developed based on the property of solid compounds with open structures having extremely high coefficients of absorption for gases at cryogenic T. A gas pipetting apparatus was constructed whereby a known quantity of a gas or gas mixture can be drawn into the experimental capsule by placing it in a low-T bath. A highly-absorptive solid, such as a zeolite or a gel, is included in the experimental charge. Due to the properties of absorption of these compounds, the resultant vapor P are normally well below 1 mm Hg. The technique is particularly effective for mixtures of non-condensed gases and avoids fractionating the gases between the condensed phase and the coexisting vapor. Of particular importance is the C-O-H-N system. Synthetic FI with fluids containing CO_2, CH_4, N_2, and H_2O have been grown. Gas chromatography using a specially designed puncturing device for the capsule was employed to verify the bulk compositions of the C-O-H-N gases generated in the experimental charges. Close agreement of the mole ratios of the initial compositions loaded into the experimental capsules and the measured compositions determined after quenching demonstrates the precision of both the gas loading and the gas chromatographic techniques. Mass spectrometry and Raman spectroscopy of the individual FI also agreed with these results and verified the existence of a homogeneous fluid.

The potential of being able to produce FI at varying T and P containing known amounts of mixed volatiles is an important step towards the use of synthetic FI in (1) determining the PVT properties of mixed volatile fluids; (2) interpreting natural FI; and (3) understanding and calibrating the microanalytical methods utilized in the quantitative analysis of natural inclusions (i.e., Raman spectroscopy, infrared spectroscopy, and mass spectroscopy). (Authors' abstract)

FRANTZ, J.D., ZHANG, Y.-G., HICKMOTT, D.D. and HOERING, T.C., 1989a, Techniques for experimentally loading and analyzing gases and their application to synthetic fluid inclusions: Ann. Rept. Dir. Geophys. Lab., Carnegie Inst. Wash. 1988-1989, p. 59-65.

FRANTZ, J.D., ZHANG, Y.-G., HICKMOTT, D.D. and HOERING, T.C., 1989b, Hydrothermal reactions involving equilibrium between minerals and mixed volatiles. 1. Techniques for experimentally loading and analyzing gases and their application to synthetic fluid inclusions: Chem. Geol., v. 76, p. 57-70. Authors at Geophysical Lab., Carnegie Inst. of Washington, Washington, DC 20008.

See previous abstracts. (E.R.)

FRANZ, G., THOMAS, S. and SELVERSTONE, J., 1989, Fluids in eclogites: Evidence from high-pressure veins in the Austrian Alps (abst.): Eos, v. 70, p. 1377. First author at Institut für Petrologie, EB 310, Technische Universität Berlin, 1000 Berlin, 12, F.R.G.

The formation and development of a fluid phase in eclogites is of critical importance for the understanding of fossil subduction zones. In the central Tauern Window, Austria, such a zone is preserved in a schuppen zone (Eclogite Zone) between overthrust ocean floor material (Upper Schieferhülle) and the underlying basement complex (Lower Schieferhülle). Fluid development in the ecologites is documented by a wide variety of high-P mineral segregations and veins containing quartz, omphacite, kyanite, zoisite, epidote, white mica, talc, garnet, glaucophase, winchite, chloritoid, tourmaline, magnesite, dolomite, rutile, apatite, pyrite, and chalcopyrite. These minerals formed at or near peak metamorphic conditions (20 kbar/600°C) with P(fluid) at least instantaneously $\geq$ P (litho). There is no obvious correlation between vein mineralogy and either host rock mineralogy or structural setting. In contrast, younger cross-cutting veins and alteration fractures show a relatively monotonous mineralogy of quartz, albite, calcite, dolomite, chlorite, ± Ca-amph ± sphene ± rut ± hem. FI in the early veins contain (1) H_2O-$CaCl_2$-$NaCl$-KCl fluids ($\leq$40 wt %

salts) with a variety of observed dms (NaCl, KCl, $CaCl_2$, Ca-sulfate, apatite, calcite, dolomite, hematite, rutile, cpx?, glauc?, white mica?); (2) CO_2; and (3) CO_2-N_2 fluids.

The field, petrologic, and fluid inclusion data on the early veins suggest a model involving (1) production and internal buffering of an H_2O-rich fluid phase at high P and T; (2) transport of Si, Na, K, Ca, Al and Ti as a result of incongruent solution of the rock on a small scale; (3) deposition of the fluids in boudin necks, fold hinges, along lithologic contacts, etc. (early veins). There is no indication of large-scale metasomatism. With decreasing P (due to buoyant tectonic uprise) from 60 km to ≤30 km, the free fluid phase escaped, but dehydration and decarbonation reactions still provided internal buffering with the production of Ca-rich solutions and transport of Si, Na, K, Fe. Fluid movement during this stage was infiltrative and channelized in cracks and shear zones (younger veins), at least on a local scale. The data imply very different physical (migration behavior) and chemical (element solubilities) properties of the high- and moderate-P fluids. Based on these results, we suggest that caution should be used in extrapolating the results of fluid behavior studies from one depth to another in high-P regimes. (Authors' abstract)

FRAPE, S.K., FRITZ, P., SHERWOOD LOLLAR, B., BLOMQVIST, R. and McNUTT, R.H., 1989, The geochemistry and possible origins of saline waters and brines from the Canadian and Fennoscandian Shields (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A316.

FRENTZEL-BEYME, K., 1988, Porosity and fluid flow in rocks of the lower crust (abst.): Fortsch. Mineral., v. 66, part 1, p. 37 (in German).

The Central European lower crust rocks and their equivalents submitted to retrograde metamorphism yield the type and volume of porosity as typomorphic characteristics. Quartz from such rock types from Sweden, Norway and Portugal has an average open residual porosity of 0.28 vol %. Comparable rocks from the Saxonian granulite outcrops had porosity of 0.1 vol %, granulite-facies quartz from Waldviertel (Austria) had 0.2 vol %. Retrograde amphibole facies metamorphosed quartz of granulitic origin from Central Schwarzwald yielded porosity of 0.4 vol %. Intensive pervasive fluid activity may lead to feldspar alteration and quartz dissolution (up to 23% of quartz volume) and result in porosity up to 4 vol %, as was found in rocks from the lower crust. Channelway fluid flow is typical of the rocks of upper crust, resulting frequently in open cleft systems; the quartz porosity equals here ca. 7 vol %. (From the author's abstract translated by A.K.)

FRENTZEL-BEYME, Klaus, 1989, SEM-cathodoluminescence structures in metamorphic quartz: Review and geological interpretation: PhD dissertation, Univ. Göttingen, 78 pp. + 54 photos (in German, translated and modified by the author, plus editing by E.R.). Author at VG Instruments GMBH Hasengartenstrasse 14, Postfach 58 69, 6200 Wiesbaden, FRG.

Cathodoluminescence in a scanning electron microprobe (SEM-CL) is a proven method to investigate semiconductor materials that is now applied to 197 specimens of metamorphic and igneous materials. SEM-CL helps to clarify the complexities of the age and history of fluid inclusions, since different trace elements in a given mineral result in different CL characteristics. Syntaxial intergrown quartz, mineralized by different fluids, show remarkable CL differences, and numerous CL-visible structures were found. Most samples examined were from Schwarzwald, Oberpfalz, Saxonian Granulite Mountains (all FRG) and Waldviertel (Austria). The porosity and CL-structures in different minerals, mostly quartz, were inspected and classified, and quantified in 75 samples. Fluid content of the porosities was determined microthermometrically.

Four major classes of SEM-CL structures are recognized:

1. This class is recognized by its good correlation with fluid inclusions, alteration phenomena in the rock and rehealing of open structures by hydrothermal minerals, mostly quartz. Four subclasses could be defined on the geometry and porosity of the CL structures: (1.1) *Channelway structures* built by hydrothermal mineralization of cracks. In a single grain their fluid inclusions (FI) are S. Fluid chemistry is aqueous with varying, often high, salinity. Average pore size is 6.0 μm^2 but varies with fluid chemistry. The mean porosity is 6%, falling to 1% with H_2O-CO_2 inclusions. (1.2) *Cracking structures* are born by hydrothermal rehealing after explosive fluid decrepitation. Star-shaped areas are interconnected by thin lines in which FI are concentrated. More than two-thirds of metamorphic and magmatic rocks examined contain these structures in quartz. The mean pore size is 5 μm^2. The average porosity in these structures is 7% but varies widely in different rocks and source regions. Cracking structures are typical in

granites, pegmatites and rhyolites. The FI have low to medium salinity, with fluid density between 0.9 and 0.6 g/cm^3. Distribution appears to be secondary or in decrepitation clusters. (1.3) *Pervasive structures* typically follow grain boundaries. They occur with different intensity in quartz and feldspars. In feldspars they are accompanied by alteration and open secondary leaching porosity. In quartz grains the boundary between older and younger quartz often appears blurred. The average pore size is 3.5 µm^2. Porosity varies locally and with rock type, with the highest quantities found in anatectic rocks. Rocks of central Schwarzwald, supposed to be an ancient seismic low velocity channel, show them in highest quantities. The FI are of aqueous, low density type ($\leq$0.6 g/cm^3). Different interpretations are possible. Long lasting or polyphase hydrothermal mineralization seem to be possible. (1.4) *Single crack structures* appear as straight lines with width not exceeding 5 µm. Gneisses and lower crustal rocks contain them in the same quantities. The average pore size is 3.2 µm^2. In quartz they always constitute <1%. Their average internal porosity is 10%. Image analysis allows a clear decision between single crack and channelway structures.

2. Growth structures like chevron and sector growth are visible in hydrothermal quartz. Growth rims, resorption and corrosion structures were seen in granite- and rhyolite-quartz. Zircon and kyanite often show contrasting growth zonation in CL.

3. Radiogenic damage in quartz was seen around radioactive minerals and along pathways through which radioactive charged fluids moved.

4. Kryptocataclastic structures are rehealed cataclastic structures. SEM-CL makes them much more clearly visible than inspection by light microscopy. Three subgroups could be classified: (4.1) *Impact cataclasis* is due to meteorite impact. Numerous polygonal clasts of widely varying size are cemented by hydrothermal quartz. (4.2) *Tectonic cataclasis* is limited to shear zones. Their phenomenology was worked out on drilling chips from the KTB deep drilling project. (4.3) *Cryptocataclasis*, mostly found in lower crustal rock quartz, is a special case. After long electron bombardment, a network of bright lines becomes visible. The nature and interpretation of this cryptocataclasis is ambiguous.

The paleofluid migration structures found are the basis for a model of fluid migration in the continental crust. The upper crust shows fluid migration in open cracks. Evolution of these cracks cannot be elucidated by SEM-CL work. The permeability of the middle crust is mainly supported and dominated by natural decrepitation of fluid inclusions. Cracking structures are often connected to pervasive structures when they extend beyond the grain boundary. This is proven in granites of south Schwarzwald region.

A zone of enhanced electrical conductivity and reduced seismic p-wave propagation below the central Schwarzwald is modelled by free fluid flow in cracking and, with increasing depth, pervasive structures. Single crack and cryptocataclasis structures are mostly found in lower crustal rocks but also sometimes in gneisses. A clear decision on their place of origin in the crustal profile is impossible. A rough estimation, based on the existing data basis, points to deep middle to lower crust. (Author's abstract)

The 54 glossy, 80 x 80-mm photographs making up plates 1-9 in this thesis are particularly instructive but could not be reproduced here. (E.R.)

FREZZOTTI, M.L., 1989, Melt inclusions in Mt. Genis leucogranite (SE Sardinia, Italy): Alkali chlorides in a granite magma (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 33. Author at Dipart. Sci. della Terra, Via delle Cerchia n.3 53100 Siena, Italy.

The M. Genis leucogranite (SE Sardinia), one of the youngest post-tectonic Hercynian intrusions, is a medium-fine grained rock consisting of quartz, perthitic feldspar, sodic plagioclase and minor biotite. The intrusion is high level, has a distinctive reddish appearance and shows a quite pronounced argillic alteration. Mm-sized miarolitic cavities are ubiquitous, filled by all the primary minerals.

Microthermometric and microprobe analyses have been performed on 15 samples for different depths (up to 150 m).

Melt inclusions, generally devirified, are found in rock-forming quartz and in quartz crystals in the miarolitic cavities. Melt inclusions are generally considered to be P in origin, with dimensions varying from 1-2 µm up to 60 µm. The bubble size is between 15 and 40 vol %, and no liquid is ever observed. FI of different salinities and Th are also present. The first trapped fluids are likely to be brines (salinity ~65 wt % NaCl eq.) characterized by Th ~500°C and Ts NaCl [i.e., Tm NaCl?] ~570°C.

Microthermometric analyses on melt inclusions show that melting starts at ~700-750°C and the final Th (disappearance of the bubble) is attained in a 100-300°C interval. In some inclusions at high T (~800°C), two immiscible melts (L_1 and L_2) of very contrasting viscosity and different refractive index are present. On quenching, L_1 produces glass while L_2 crystallizes as solid cubes around the vapor bubble. These features, together with preliminary microprobe analyses on heated melt inclusions, indicate that mixed Na, K chlorides and a high silica glass are present.

The above results indicate that, during final granite crystallization, only a salt melt was present along with residual silicate magma, and that the brines probably circulated at subsolidus conditions during high T hydrothermal stages. (Author's abstract)

FREZZOTI, M.L. and **GHEZZO, C.**, 1989, Fluid phase evolution in the Mt. Genis leocogranitic [leucogranitic] intrusion (SE Sardinia, Italy) (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 98. Author at Dipart. Scienze della Terra, Siena, Via delle Cerchia n. 3, 53100 Siena, Italy.

See previous item. (E.R.)

FRIEDMAN, G.M., 1989, Case history of deep-burial sulfide mineralization in the northern Appalachian Basin: Carbonates and Evaporites, v. 4, no. 2, p. 231-241. Author at Dept. Geol., Brooklyn College-City Univ. New York, Brooklyn, NY 11210.

In the northern Appalachian Basin minor concentrations of sulfide mineralization occur throughout most of the undeformed strata, especially those composed of carbonate rock. In a hostrock of gray, dense, hard, massive, fine-grained dolostone (dolomicrite) the Lockport Formation (Middle Silurian) contains a remarkable mineral suite filling fractures, vugs, and cavities, especially a geode filling of former leached anhydrite nodules. The minerals include saddle dolomite, sphalerite, galena, marcasite, pyrite, fluorite, anhydrite and gypsum (mostly selenite), calcite, quartz, barite and celestite.

Fluid inclusions trapped during the growth of this mineral assemblage indicate that the precipitating fluids were very hot and highly saline; T hovered near 150°C and the salinity exceeded that of seawater by three to seven times. Considering a paleogeothermal gradient of 26°C/km (Friedman and Sanders, 1982; Friedman, 1987a), maximum burial depth of the Lockport Formation, at which the mineral assemblage probably formed, was 5 km. Investigators have concluded that most MVT deposits precipitated 250 to 200 m.y. ago from hot brines but migrated through sedimentary strata (Geol. Soc. Am., 1989). This age coincides with the Allegheny orogeny. Uplift was accompanied by erosion. Further uplift and erosion, probably during the Cretaceous and Late Tertiary, brought this formerly deeply buried mineral deposit to the present land surface. This paper shows how through uplift and erosion a mineral deposit that formed at the great depth of 5 km was brought to the earth's surface. (Author's abstract)

FRISCHBUTTER, V.A., THOMAS, R. and **TAUBER, F.**, 1989, Thermobarometric investigations of fluid inclusions in quartz: Z. geol. Wiss., v. 17(11), p. 1041-1052 (in German, English abstract).

Results of thermobarometric investigations of liquid inclusions in quartz from two different deformational evolutions, starting from the same parent rock, are interpreted with respect to their time-dependence. The conditions for the formation of the "red gneiss-parent rocks" in the Erzgebirge Mts. due to complete recrystallization of quartz cannot be determined by the applied method. Data to answer this question were derived from chemical comparisons with conditions of the post-Variscan granites in the Erzgebirge Mts.

T and P values of the inclusions (rock) formation, derived from Th of the inclusions, characterize the folding process of an older crystalline schistosity plane (increasing P/T conditions). Furthermore, in connection with the formation of partial melts (reaching the liquidus-solidus border of granitic systems, i.e., the formation of the so-called "basal granitoids") and with the formation of pencil gneisses (rotational structures) there appears a combined P-T drop, followed by a further decrease to hydrothermal conditions. The P drop in connection with the formation of rotational structures takes place definitely before the formation conditions of partial melts are reached. The P drop of the entire process may amount to ~2 kbar. The formation depth of the red-gneiss parent rocks in the Earth's crust in the Erzgebirge should be markedly lower than that of the post-Variscan granites ($\gtrsim$5 km). (Authors' abstract)

FRITSCH, Emmanuel and **SCARRATT, K.V.G.**, 1989, Optical properties of one type of natural diamonds with high hydrogen content (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 21-22.

FROST, B.R., FROST, C.D. and TOURET, J.L.R., 1989, Magmas as a source of heat and fluids in granulite metamorphism, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 1-18. First author at Dept. Geology and Geophysics, Univ. Wyoming, Laramie, WY 82071.

Three diverse modes of granulite formation, CO_2-streaming, partial melting, and recrystallization of originally anhydrous rocks, can be aspects of the same process: movement of magmas through the lower crust. CO_2-saturated silicic and mafic magmas can exsolve enough CO_2 to dehydrate a volume of country rock ~=20% that of the magma itself. Consequently, movement of magmas through the crust can provide both the heat and the CO_2 necessary for granulite metamorphism. Furthermore, silicic magmas emplaced into the deep crust are likely to produce anhydrous pyroxene-bearing cumulates (i.e., charnockites) while more hydrous portions of the magma would be forced to migrate to shallower, cooler levels before they could crystallize to the H_2O-saturated liquidus. Thus, magmas may form conduits by which CO_2 of mantle origin is transported into the lower crust while H_2O is extracted from the lower crust and moved to shallower levels. Evidence supporting this hypothesis lies in the abundance of CO_2 fluid inclusions in clearly igneous charnockitic rocks, in the elevated geotherms suggested by P-T conditions of some granulites, and in the relict igneous features found in the highest grade areas of some granulite terranes. This theory implies that some felsic rocks with high K/Rb ratios may be cumulates, and that such K/Rb ratios are not diagnostic of CO_2-fluxing. (Authors' abstract)

FROST, B.R., FYFE, W.S., TAZAKI, Kazue and CHAN, Tammy, 1989, Grain-boundary graphite in rocks and implications for high electrical conductivity in the lower crust: Nature, v. 340, p. 134-136. First author at Dept. Geology and Geophysics, Univ. Wyoming, Laramie, WY 82071.

The origins of zones of high electrical conductivity in the lower continental crust is a long-standing mystery; possible explanations include the presence of brines, partial melt, serpentine, and graphite. When discussing the occurrence of graphite in the crust, many petrologists have considered phase relations as they would have existed at the peak of metamorphism or during igneous emplacement. Here we show that a fine film of graphite is present on the grain boundaries in three rocks from the Laramie Anorthosite Complex. In two of these rocks graphite was stable during igneous crystallization but in the other it was not. We maintain that in all of the rocks the grain-boundary graphite precipitated from a CO_2-rich fluid during cooling. The chemical processes that produced the grain-boundary graphite in these rocks are likely to operate in many lower-crustal rocks. We therefore contend that, because the films we observe are capable of producing the high conductivity that is seen in the lower crust, grain-boundary graphite should be considered as a possible cause for some conductivity anomalies. (Authors' abstract)

See also "News and Views" report on this paper in Nature, v. 340, p. 102, and Bailey et al., this volume. (E.R.)

FROST, B.R. and TOURET, J.L.R., 1989, Magmatic CO_2 and saline melts from the Sybille Monzosyenite, Laramie Anorthosite Complex, Wyoming: Contrib. Mineral. Petrol., v. 103, p. 178-186. First author at Dept. Geology and Geophysics, Univ. Wyoming, Laramie, WY 82071.

There are three populations of fluid inclusions in quartz from the Sybille Monzosyenite: early CO_2, S CO_2, and rare S brines. The oldest consist of low density CO_2 ($\rho \cong 0.70$) inclusions that appear to be comagmatic. The densities of these inclusions are consistent with the inferred crystallization conditions of the Sybille Monzosyenite, namely 3 kbars and 950-1000°C. The other types of inclusions are S; they contain CO_2 ($\rho \cong 0.50$) and S brine inclusions that form trains radiating out from a decrepitated inclusion. The sites of these decrepitated inclusions are now marked by irregularly shaped fluid inclusions and solid inclusions of salt and carbonate. Rather than fluid inclusions feldspar contain abundant solid inclusions. These consist of magmatic minerals, hedenbergite, hornblende, ilmenite, apatite, and graphite, intimately associated with K, Na chlorides. We interpret these relations as follows: The Sybille Monzosyenite formed from a magma that contained immiscible droplets of a halide-rich melt along with a CO_2 vapor phase. The salt was trapped along with the other obvious magmatic minerals during growth of the feldspars. CO_2 may have also been included in the feldspars but it probably leaked later during exsolution of the feldspars and was not preserved. Both the saline melt and the CO_2 vapor were trapped in the quartz. The melt inclusions in the quartz later decrepitated, perhaps due to progressive exsolution of fluids, to produce the S H_2O and CO_2 inclusions. These observations indicate that the Sybille Monzosyenite, which is a markedly anhydrous rock, was actually vapor-saturated. Rather than being H_2O, however, the vapor was CO_2-rich and possibly related to an immiscible chloride-rich melt. (Authors' abstract)

FROST, K.M. and **GROVES, D.I.**, 1989, Magmatic contacts between immiscible sulfide and komatiite melts: Implications for genesis of Kambalda sulfide ores: Econ. Geol., v. 84, p. 1697-1704.

FURMAN, F.C. and **MISRA, K.C.**, 1989, Shales as a source of mineralizing fluids for Mississippi Valley-type deposits: Examples from Illinois-Kentucky and East Tennessee districts (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-519.

GALIMOV, E.M., BOTKUNOV, A.I., GARANIN, V.K., SPASENNYKH, M.Yu., BANNIKOVA, L.A., NIKULINA, I.V., SHISHMAREVA, L.E., and **BELOMESTNYKH, A.V.**, 1989, Carbon-containing fluid inclusions in garnet and olivine from kimberlites of the Udachnaya pipe [USSR]: Geokhimiya 1989, (7), p. 1011-1015 (in Russian). Authors at Inst. Geokhim. Anal. Khim., U.S.S.R.

Olivine and garnet (pyrope) crystals from kimberlites of the Udachnaya Pipe (USSR) were studied by optical microscope and electron microprobe; gases from the FI of these crystals were analyzed by mass spectroscopy. When pulverized, Ol crystals with transparent vesicles yielded gas, the mass spectrum of which indicated the presence of high-mol ($\geq C_2$) org. compds. and N_2. CO_2 is present in subordinate amt. The gases from pyrope grains had similar characteristics. This indicates that the pyropes and chrysolites in the kimberlites crystd. in equil. with hydrocarbon-N_2 fluids. The isotope compn. of C from the FI in Ol crystals, detd. in 2 fractions, was $\delta^{13}C = -28.23$ and -26.56‰. In the 2nd fraction C is present as CH_4 (and possibly CO). Thus, the reduced C in the FI is enriched in the light isotope. Mantle fluids contg. CH_4 and other reduced forms of C compds. were a possible source of the fluid trapped in the Ol and garnet. (CA 111:118292k)

GALLAGHER, V., 1989, Geological and isotope studies of microtonalite-hosted W-Sn mineralization in SE Ireland: Mineral. Deposita, v. 24, p. 19-28. Author at Dept. Geol., Univ. College, Dublin, Ireland.

A swarm of Caldeonian microtonalite sheets is host to W-Sn mineralization in SE Ireland. Many but not all mineralized sheets are within a regional shear zone which, however, does not appear to have been a major control on mineralization. Scheelite and arsenopyrite are the dominant minerals within and adjacent veins in greisened tonalite. No wolframite occurs. The intrusions are affected by two alterations, a pervasive one and another which is spatially associated with veins. Both are associated with high metal values. Veining is confined to microtonalite sheets and was initiated at least partly by hydraulic fracturing of the intrusions. Stable isotope analyses indicate that mineral deposition occurred over narrow time and T intervals from a hydrothermal fluid of magmatic origin. Methane is important in FI in quartz veins and the low oxygen fugacity of the mineralizing fluid was probably critical in concentrating metals and in suppressing wolframite formation. (Author's abstract)

Mass spectrometric analyses were made of the gases liberated at 100-550°C from six vein quartz samples. H_2O = >95 mole % in all; CO_2/CH_4 ratios averaged 1.0, and the analyses show the fluid to be close to equilibrium with graphite. (E.R.)

GALLI, B. and **LATTANZI, P.**, 1989, New data on fluid inclusions in quartz-gold deposits of the Monte Rosa district, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 34. Authors at Dipart. Sci. della Terra, Univ. Firenza, Via G. la Pira 4, I50121 Firenze, Italy.

Several late-Alpine quartz-Au deposits occur in diverse terranes overthrust and metamorphosed during the Alpine orogeny in the Monte Rosa area (NW Alps, Italy). We report here FI data from the deposits at Val Toppa and Miniera dei Cani.

At both localities, FI in vein quartz are either triphase (aqueous brine + CO_2 liquid + CO_2-rich gas) or biphase (aqueous brine + vapor) at room T. In triphase inclusions, the carbonic phase probably contains minor CH_4 (confirmed, at Val Toppa, by preliminary Raman microanalyses). CO_2 generally has Th L, mostly in the range 22-29°C. Salinities of the aqueous phase (derived from T clath) are comparable at both localities, ranging from near zero to about 8% wt. NaCl eq. At Val Toppa total Th L occurs between 205 and 288°C, with a well-defined peak at ~260°C. At Miniera dei Cani, total Th may occur to liquid, gas, or the critical mode at between 283 and 357°C, with a well-defined peak at ~320°C. The triphase inclusions of Miniera dei Cani may result from heterogeneous trapping of immiscible CO_2-rich and H_2O-rich fluids.

Biphase inclusions are especially abundant at Val Toppa. They have widely variable salinities (about 1 to 15% wt. NaCl eq.), and Th tot between 142 and 241°C, with a well-defined peak around 230°C. A few measurements on biphase inclusions at Miniera dei Cani also indicate a wide range of salinities (near zero to ~10 wt % NaCl eq.) and Th 172 to 258°C.

The present data are in agreement with the previously suggested metamorphic nature of the Au-forming fluids in the district, with significant contributions of meteoric fluids at Val Toppa, as demonstrated by previous O-isotope studies. (Authors' abstract)

GALLUP, D.L., 1989, The solubility of amorphous silica in geothermal brines: Geothermal Resources Council, Trans., v. 13, p. 241-245.

GAMMONS, C.H., 1988, Studies in hydrothermal phenomena: (1) The solubility of silver sulfide in aqueous sulfide solutions to 300°C; (2) A paragenesis and fluid inclusion study of polymetallic vein mineralization in the Big Creek mining district, central Idaho: Dissertation, Pennsylvania State Univ., University Park, PA, Univ. Microfilms Int., No. DA8909994. (Diss. Abstr. Int. B 1989, 50(2), 465.)

GAMMONS, C.H. and BARNES, H.L., 1989, The solubility of Ag_2S in near-neutral aqueous sulfide solutions at 25 to 300°C: Geochim. Cosmochim. Acta, v. 53, p. 279-290.

GAMOV, M.I., SAFAROV, Yu.A. and TRUFANOV, V.N., 1988, Heterogeneous ore-forming fluid systems of Tyrnyauz: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 37 (in Russian). Authors at Rostov State Univ., Rostov-on-Don, U.S.S.R.

A general presentation of the features of ore-forming solutions at the W-Mo deposit of Tyrnyauz, boiling of CO_2-rich fluids occurred at 500-550°C, 600-800 bar. (A.K.)

GANEYEV, I.G., 1989, Transport of materials by hydrothermal solutions: Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva, 1989, v. 118, no. 1, p. 3-16 (in Russian; translated in Int'l Geol. Rev., v. 31, p. 431-441). Author at Inst. of Lithosphere, USSR Academy of Sciences, Moscow, U.S.S.R.

The author presents a model, based on experiments with solutions and conditions indicated by FI in minerals of vein deposits, that indicates a major role for hydrolysis of electrolytes and transport as heteropolyanions. Changes in the structure and properties of the solutions as they move through the thermal gradient in the vein system are of major importance. (From author's abstract)

See also Ganeev, I.G., 1988, Fluid Inclusion Research, v. 21, p. 120. (E.R.)

GARCIA, M.O., MUENOW, D.W., AGGREY, K.W. and O'NEIL, J.R., 1989, Major element, volatile, and stabile isotope geochemistry of Hawaiian submarine tholeiitic glasses: J. Geophys. Res., v. 94, no. B8, p. 10,525-10,538. Also in 28th Int'l Geol. Cong. Abstracts, p. 1-529. First author at Hawaii Institute of Geophysics, Univ. Hawaii, Honolulu, HI 96822.

Tholeiitic glasses were dredged from the submarine rift zones of the five volcanoes comprising the island of Hawaii and Loihi Seamount. The major element composition of the glasses follows a systematic trend that is related to the stage of evolution of the volcano. Glasses from Loihi Seamount (the youngest Hawaiian volcano) are enriched in Fe, Ca, Ti, Na and K and depleted in Si and Al relative to the glasses from the other, older volcanoes. Kilauea is intermediate in age and its glasses are intermediate in composition between those from Loihi and Mauna Loa, the largest and oldest of the active Hawaiian tholeiitic volcanoes. The volatile contents (H_2O, CO_2, S, F, Cl) of the glasses from these volcanoes follow the same trend (highest in Loihi; lowest in Mauna Loa). Glasses from Hualalai Volcano are similar in composition to those from Mauna Loa; those from Kohala Volcano are similar to Kilauea; Mauna Kea glasses range from Mauna Loa-like to Kilauea-like. The observed systematic variation in composition of Hawaiian tholeiites may be related to the progressive melting and depletion of the source of these volcanoes during their growth. O and H isotope analyses were made on many of the glasses from each volcano. The $\delta^{18}O$ values of Hawaiian tholeiites are distinctly lower than those of mid-ocean ridge basalt (MORB) (averages: 5.1 versus 5.7). These low values are probably a distinct feature of hot spot lavas. The δD values for these glasses (-88 to -61) are typical of mantle and MORB values. Thus the H_2O in the Hawaiian glasses if probably of magmatic origin. Previous isotopic and trace element data indicate that the source of Hawaiian tholeiites contains two distinct source components. Based on the results of this study, the plume component in the source for Hawaiian tholeiites is characterized by moderate $^{87}Sr/^{86}Sr$ (0.7035-0.7037) and $^{206}Pb/^{204}Pb$ ratios (18.6-18.7) a low $\delta^{18}O$ values (~5.0), and greater contents of volatiles, Fe, Ca, Ti, Na and K relative to the MORB source. (Authors' abstract)

GARCIA IGLESIAS, J. and **LOREDO, J.**, 1989, Geological, geochemical and mineralogical investigations of the Carles gold deposit, Asturias, Spain (abst.): Terra abstracts, v. 1, p. 28.

In the Cantabrian Zone, Carlés Au [+ Bi] deposit is related to the metamorphic aureole of a Hercynian granodioritic stock in Devonian limestones. [It occurs] either in quartz-veins or in the altered rocks in proximity to quartz-veins inside the contact metamorphic aureole. Cu sulfides are also present.

In apparently contemporary fluid inclusions, presence of CO_2 and differences in salinity and density are confirmed. Th of fluid inclusions in quartz are 320-340°C and increase with a correction corresponding to P of 1000-1200 bars. [Hence] it follows that Tf of quartz should be ~450°C.

Mineralizing fluids seem to be associated with fracturing and decompression processes in the granodiorite and its metamorphic contact aureole. (From authors' abstract by E.R.)

GARVEN, Grant, 1989, Paleohydrology of brine migration and ore formation in sedimentary basins of the Midcontinent region (abst.): Eos, v. 70, p. 1097. See also other papers in same session. (E.R.)

GATES, J.A. and **WOOD, R.H.**, 1989, Density and apparent molar volume of aqueous $CaCl_2$ at 323-600 K: J. Chem. Eng. Data, v. 34, p. 53-56.

GATTER, I. and **SZEBENYI, G.**, 1989, Fluid inclusion studies on the Recsk Cu-porphyry system - I. "Siliceous cap", N. Hungary (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 35. First author at Eotvos Lorand Univ., Mineral. Dept., H-1088 Budapest, Muzeum Krt. 4/a, Hungary.

The Recsk ore-bearing complex, NE Matra Mts., N. Hungary contains various types of sulphide, which are genetically related to each other. The area consists of Upper Eocene neutral, calc-alkaline plutonic-volcanic rocks which were extruded and intruded in five phases into, and onto a tectonically deformed Triassic sedimentary sequence. Due to the lack of (or relatively little) erosion nearly all the types of ores from the "porphyry copper environment" can be observed: (i) metasomatic Cu-skarn ore; (ii) Cu-Mo porphyry ore; (iii) replacement-metasomatic Zn-Pb-Cu ore; (iv) near-surface volcanogenic massive-stockwork Cu-As-pyrite ore ("siliceous cap").

A detailed FI investigation has been carried out [on] the siliceous cap ores. The main sulphide mineral association comprises a galena-sphalerite-pyrite-chalcopyrite-tennantite assemblage, which occurs in irregular distributions, as veinlets and as pockets of ore in the lower part of the stratovolcanic sequence (biotite-amphibole-andesite). These ores are accompanied by silicification, clay mineralization and alunitization. Several types of FI are present, as follows: (i) vapor-rich inclusions (some samples show boiling phenomena); (ii) monophase aqueous liquid inclusions; (iii) two-phase aqueous (V + L) inclusions; (iv) three-phase aqueous liquid (V + L + S) inclusions; (v) immiscible liquid inclusions (rare, mainly CO_2).

The Th values are bimodal with groups at 220-260°C and 270-290°C respectively. On the basis of cryoscopic investigations, the inferred Te and Tc[sic] values show, that the fluids have a mixed-juvenile-magmatic and descendent-lateral secretion characteristics (alkaline-alkaline earth chloride + alkaline sulphate/bicarbonate). The salinity and density of these fluids varies from 1 to 2.25 (5.75) wt. % NaCl eq. and 0.75 to 0.85 g/cm^3.

The development of ore-forming fluids is spatially well controlled. Over the porphyry stock is a thermal plateau of 230-250°C. The fluids in the central part of the ore field contain heterogeneous H_2O-CO_2 mixtures, forming an aureole-like distribution, which is coincident with a local enrichment of base metal sulphides. Other physicochemical parameters derived from the FI study provide valuable information concerning the extent and distribution of the deposits. (Authors' abstract)

GAUTHIER-LAFAYE, F. and **WEBER, F.**, 1989, The Francevillian (lower Proterozoic) uranium ore deposits of Gabon: Econ. Geol., v. 84, p. 2267-2285. Authors at Centre de Sédimentologie et de Géochemie de la Surface (C.N.R.S.), 1, rue Blessig, 67084 Strasbourg Cedex, France.

The lower Proterozoic U ore deposits in the Franceville basin (Gabon) are the oldest high-grade U accumulations known. They are unique in that they contain evidence for natural nuclear fission reactors.

Sedimentologic, tectonic, petrographic, and geochemical studies have been performed in order to reconstruct the geologic conditions in which U mineralization took place. U deposits are located in deltaic sediments overlying fluviatile deposits of coarse sandstone and conglomerates which are the source rocks for U. Deltaic sediments are overlain by marine black shales (the FB formation). Petrographic observations, electron microscope studies, and geochemical and carbon isotope data indicate that these FB black shales are source rocks for petroleum trapped in the U deposits.

Tectonic studies show that all the U deposits are in tectonic structures that served as traps for both petroleum and U. U mineralization occurs in this setting when an oxidized U-bearing fluid has mixed with a reduced petroleum-bearing fluid. The U ores are affected by hydrofracturing which forms a good pathway for the oxidized U-bearing fluids and the reduced fluids. Hydrofracturing may be initiated by overpressured fluids coming from undercompacted zones in the FB black shales. (Authors' abstract)

Fluid inclusion data (p. 2276-2279) may be from the literature or may be new data(?). (E.R.)

GAVIGAN, T.H., **NASH, W.H.** and **WEBSTER, J.D.**, 1989, Preeruptive gradients in silicic magma as recorded by melt inclusions (abst.): Eos, v. 70, p. 1417. First author at Dept. Geology and Geophysics, Univ. Utah, Salt Lake City, UT 84112.

Analyses of melt I in quartz phenocrysts by electron probe microanalysis (EPMA) and secondary ion mass spectrometry (SIMS) reveal gradients in volatile constituents and some major and trace elements in the preeruptive magma body of the Honeycomb Hills, Utah, rhyolite complex. EPMA estimates of H_2O content as determined from the difference in measured O and stoichiometrically calculated O agree closely with H contents measured directly by SIMS. Melt I from early erupted pumice contain 4.5-5.5 % H_2O, declining slightly to 3.4-4.2% in intermediate pumice, 2% at the top of the pyroclastic sequence, and eventually 0.8-2.0% in domal lavas. Similarly, fluorine contents decrease from 3.5% in melt I in early pumice to 2.5% in vitrophyre and 1.7-2.5% in domal lavas. Cl increases in melt I in the eruptive sequence from 1000 ppm in early pumice to 2000 ppm in dome-forming lavas. Based upon experiments on an analogous composition from Spor Mountain, Utah, 4.5% H_2O would result in vapor saturation at 1 kb or ~3 kb depth. The magma volume that gave rise to the domal lavas was initially undersaturated with respect to H_2O and degassed passively during passage to the surface.

Elements whose preeruptive concentrations in melt I are significantly greater than in glass or whole rock include Be, B, Sn and Cs, and to a lesser extent Li, Na and Cl. We interpret these to have been preferentially partitioned in the vapor phase during explosive and passive degassing of the magma. Conversely, Y, U, Th, La, Ce and Fe are relatively enriched in the whole rock compared to melt I. At the Honeycomb Hills these elements are strongly incorporated into a variety of accessory phases. Other elements such as Rb, Mn, Ti, Si and K do not differ significantly between melt I and whole rock concentrations. (Authors' abstract)

GEGUZIN, Ya.E., **KRUZHANOV, V.S.** and **STARUKHINA, L.V.**, 1988a, Threshold nature of movement of organic liquid inclusions in single crystals: Kristallografiya, v. 33, p. 990-993, 1988 (in Russian; translated in Sov. Phys. Crystallogr., v. 33, no. 4, p. 585-587, 1989). Authors at State Univ., Khar'kov.

The authors discuss the causes of the threshold nature of motion of faceted liquid inclusions, intersected by dislocations, in a single crystal. They discuss two types of threshold—contour and dislocation—for which they make elementary estimates of the threshold dimensions of the inclusions. The results agree with the results of experiments on the motion of inclusions of aqueous solution in a single crystal of KCl. (Authors' abstract)

GEGUZIN, Ya.E., KRUZHANOV, V.S. and **STARUKHINA, L.V.,** 1988b, Motion of liquid inclusions in single crystals of KCl with high dislocation density: Kristallografiya, v. 33, p. 1499-1504 (in Russian; translated in Sov. Phys. Crystallogr., v. 33, no. 6, p. 892-895, 1988 (pub. 1989)).

The authors have investigated the influence of the dislocation density in single crystals of KCl on the behavior of liquid inclusions of aqueous solution in the field of a T gradient. With increase in the dislocation density, they observe an increase in the velocity of the inclusions, due to a change in the structure of the leading dislocational source of solution. In very dislocated crystals, they also observe a change in the character of deformation of the moving inclusions. These are extended along the direction of motion, which is due to the impossibility of layerwise growth on the rear surface of the inclusion owing the stoppage of the moving steps by emergences of dislocations. (Authors' abstract)

GERLACH, D.C., BAZAN, J.M., HUNT, G.F. and **RUSS, G.P.,** 1989, ICP-MS: A tool for the masses (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A172-173.

GERLACH, D.C., WEST, H.B., THOMAS, D.M., DELANOY, G.A. and **IKEMOTO, B.N.,** 1989, Trace element geochemistry of geothermal fluids, East Rift Zone, Kilauea, Hawaii (abst.): Eos, v. 70, p. 1397.

GERLACH, T.M., 1989a, Greenhouse forcing by carbon dioxide degassing of basalt: Eruptive vs. noneruptive mechanisms (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A13.

GERLACH, T.M., 1989b, CO_2 from magma-chamber degassing: Nature, v. 337, p. 124. Author at Geosci. Dept., Sandia Nat'l. Lab., Albuquerque, NM 87185.

Discusses the degassing of magma chambers as a source for the CO_2 discharged at submarine hydrothermal vents. (E.R.)

GERLER, G. and **SCHNIER, C.,** 1989, Neutron activation analysis of liquid inclusions exemplified by a quartz sample from the Ramsbeck mine, F.R.G.: Nucl. Geophys., v. 3, no. 1, p. 41-48. First author at Institut für Geologie und Dynamik der Lithosphäre, Universität Göttingen, D-3400 Göttingen, B.R.D.

Using a combination of non-destructive and destructive methods the elements Cl, Br, I, Na, K, Rb, Cs, Ca, Sr, Ba, Fe, Co, Ag, Sb and Hg in liquid inclusions in quartz from the main phase of the Hercynian mineralization of the Ramsbeck mine have been analysed quantitatively by instrumental neutron activation analysis (INAA). The included hydrothermal solutions are dominated by NaCl. The molal concentrations of the major components are 1.1 (Na), 0.11 (K), 0.069 (Ca) and 1.2 (Cl). The freezing point depression of H_2O which has to be expected on the basis of the analytical results agrees well with the observed microthermometric data. (Authors' abstract)

GERRETSEN, J., PATERSON, M.A. and **McLAREN, A.C.,** 1989, The uptake and solubility of water in quartz at elevated pressure and temperature: Phys. Chem. Minerals, v. 16, p. 334-342.

GERSTNER, M.R., BOWMAN, J.R. and PASTERIS, J.D., 1989, Skarn formation at the MacMillan Pass tungsten deposit (MacTung), Yukon and Northwest Territories: I. P-T-X-V characterization of the methane-bearing, skarn-forming fluids: Can. Mineral., v. 27, p. 545-563. First author at Delta Environmental Consultants, Inc., Fort Collins, CO 80526.

Microthermometric and Raman spectroscopic analyses of fluid inclusions from the MacTung scheelite skarn deposit indicate that the skarn-forming fluids are water-dominant, low in salinity, and methane-bearing. In general, the measured salinities are less than 5.0 eq. wt % NaCl. Calculated values of X(CH_4) in the bulk fluid range from 0.005 to 0.02 in inclusions in pyroxene skarn, and from 0.01 to 0.04 in inclusions in garnet and quartz from both anhydrous and hydrous skarn. Carbon dioxide is a very minor component [X(CO_2) << 0.01] in the skarn fluid from all facies. The measured final Th and calculated P of the methane-bearing aqueous fluids indicate minimum Tt and Pt of 355°C and 2.1 kbar for inclusions in hydrous and garnet skarn, and 335°C and 1.4 kbars for inclusions in pyroxene skarn. On the assumption of a maximum fluid P of 2.5 kbars, many inclusions in the pyroxene, garnet, and amphibole skarns have essentially indistinguishable Tt near 380°C. The greater part of the pyroxene skarn formed at somewhat higher T, from 410 to 470°C (430°C av.). The majority of inclusions in garnet and amphibole skarns have virtually identical calculated isochores. The similarities in Tt indicate significant overlap in P-T conditions for the formation of anhydrous and initial hydrous skarn. The biotite facies of hydrous skarn began forming at similar P-T conditions, but continued to develop after pyroxene, garnet, and amphibole skarns ceased to form, as the T fell to 325°C. The fluid-inclusion data indicate that some variations in T and probably fluid P occurred within all skarn types. Fluid P closely approached lithostatic P (2.5 kbar maximum) throughout skarn development, but very likely fluctuated between probable limits of 2.1 and 2.5 kbars. Maximum decreases in T, calculated by assuming a constant fluid P, are less than 150°C from the earliest (highest T) pyroxene skarn to the latest (lowest T) biotite skarn. The most significant differences in T occur *within* anhydrous skarn development (i.e., between pyroxene and garnet skarn) and *within* hydrous skarn development (i.e., between amphibole and biotite skarn). The anhydrous garnet skarn and the hydrous amphibole skarn formed at virtually indistinguishable P-T conditions. Thus, there is no significant break in P-T conditions between the development of "prograde" anhydrous and "retrograde" hydrous skarn types at MacTung. (Authors' abstract)

GHENT, E.D., STOUT, M.Z. and PARRISH, R.R., 1989, Determination of metamorphic pressure-temperature-time (P-T-t) paths, *in* E.G. Nisbet and C.M.R. Fowler, eds., Heat, Metamorphism and Tectonics: Univ. Sask., Dept. Geological Sciences, Saskatoon, SK, Canada, Short Course Handbook, v. 14, p. 155-188.

GHIRNIS, A.V. and SOLOVOVA, I.P., 1989, Petrogenetic information value of microinclusions of melt in minerals from deep rocks: Geokhimiya, 1989, (1), p. 20-28 (in Russian, English abstract).

Effect of external P on behavior of the melt-FI in crystals in the process of their heating and the related errors of the inclusion-homogenization technique are considered. Thermodynamic calculations show that the assumption of equality of inclusion Th and Tf of the host mineral is correct only under certain relations between the fluid and general P at the moment of the inclusion capture. Experiments made in the cylinder-piston machine at P >1 atm have confirmed the calculations and permit coincidence of Th and Tf of the host mineral. (Authors' abstract)

GIAMELLO, M., PROTANO, G., RICCOBONO, F. and SABATINI, G., 1989, Fluid evolution in the Funtana Raminosa hydrothermal field, central Sardinia, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 36. Authors at Inst. Mineral. and Petrogr., Univ. Siena, Via Mattioli, 4 - 53100 Siena, Italy.

In the Funtana Raminosa area, numerous exploited Pb-Zn-Cu sulphide bodies are spatially associated with metamorphosed lenses of Silurian limestone interlayered with black shales and metasandstones. In the same area, these Hercynian metamorphic rocks are crosscut by an extensive swarm of porphyry dikes, ranging in composition from rhyolite to andesite, which are commonly deeply altered by hydrothermal activity.

Mineralized rocks have been heavily transformed by pyrometasomatic processes and a wide variety of tactites are known in the area. Garnet-, clinopyroxene- and epidote-bearing skarns are the most commonly observed rock types, with sphalerite, galena, chalcopyrite and pyrite forming the main ore minerals.

This work refers to the results of a FI study carried out on ore and gangue minerals and minerals for the altered porphyry dikes.

Inclusions found in the grossularitic cores of garnets, showing extremely high salinities and Th, are P three-phase inclusions formed during the early stage of the metasomatic processes. Andraditic rims of the same crystals are inclusion-free or show linear arrays of two-phase S inclusions of moderate salinity and lower Th (≈340°C).

Inclusions in quartz from the altered porphyry dikes are two-phase inclusions showing extremely variable vapor contents (5-90%), indicating heterogeneous trapping due to boiling. Th range from 225 to 360°C, and salinity values are variable but always below 7 wt % NaCl eq. FI in sphalerite are two-phase inclusions with a narrow range of Th (250-285°C) and salinity (3.2-4.5 wt % NaCl eq.). FI from late quartz veins, geoidic quartz and fluorite show the lowest Th (245-190°C) and very low salinity (≈1%).

The three-phase high salinity inclusions found in the grossularitic cores of garnets probably represent the trapping of a rapidly exhausting brine due to the boiling of formational fluids during the early thermal peak linked to porphyry dike intrusion. Inclusions found in the andraditic rims of garnets, and very similar inclusions present both in quartz crystals in altered porphyries and in the sphalerite crystals of the ore bodies, represent the influx of heated meteoric water into the system. The lowest T and salinity inclusions found in late quartz and fluorite represent the waning of the hydrothermal circulation and probably represent mixing with cooler meteoric water. (Authors' abstract)

GIAMELLO, M., RICCOBONO, F. and **SABATINI, G.**, 1989, The genesis of the Antonio Pb-ZnS deposit, southern Tuscany, Italy. Contrasting evidence from field, Pb-isotope, and microthermometric data (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 37. Authors at Inst. Mineral. and Petrogr., Univ. Siena, Via Mattioli, 4 - 53100 Siena, Italy.

The Pb-ZnS Antonio di Val d'Aspra deposit occurs within a lower Moscovian carbonate sequence in the Farma Valley (southern Tuscany) and shows many characteristics in common with Mississippi Valley-type deposits. Sphalerite and galena form a very simple ore assemblage, that is closely related to recrystallized and dolomitized portions of original, and locally preserved, black limestone. The mineralized carbonate rocks appear to have been eroded before the deposition of the overlying Spirifer-bearing shales of Podoskian age, the diffuse presence of structures frequently found in internal sediments of karstic cavities testifies that supergene mechanisms have played an important role in the history of the deposit.

A FI study carried out on ore and gangue minerals indicated the presence of three different types of inclusions: (i) Type I, two-phase (L + V) and have a degree of fill (% vapor) ≈15%; (ii) Type II, complex aqueous inclusions (L + V) with a degree of fill ≈10% and appreciable amounts of hydrocarbons as suggested by their freezing; and (iii) Type III, bituminous matter.

Th range from 130 to 210°C but the most commonly observed values are very close to 170°C. Salinity appears moderately low at ~5 wt. % NaCl eq. Lead isotope data rule out the hypothesis that the S. Antonio mineralization can be related to the Tertiary hydrothermal activity, responsible for other base metal occurrences in the area. In summary, a sharp contrast exists between field, petrographic and isotopic evidence on the one had and FI microthermometry on the other. Moreover, inclusions with high Th values occur not only in sphalerite, quartz and dolomite of the mineralized rock but also in calcite from the original black limestone. The only explanation seems to be a post-depositional origin for all FI, or resetting of inclusions after original trapping. (Authors' abstract)

GIBSON, E.K., Jr. and **CARR, R.H.**, 1989, Laser microprobe-quadrupole mass spectrometer system for the analysis of gases and volatiles from geologic materials: U.S. Geol. Surv. Bull. 1890, p. 35-xx. First author at Planetary Sciences Branch, NASA Johnson Space Center, Houston, TX 77058.

A laser microprobe connected to a computer-controlled benchtop quadrupole mass spectrometer is capable of extracting gases and volatiles from a wide variety of geologic materials. The released gases are identified by mass spectrometry. A capacitance manometer is used to quantify the yield of released gases. Reference minerals have been analyzed in order to determine the nature of volatiles released by laser interaction with the surfaces. Minerals analyzed include carbonates (calcite, magnesite, dolomite, and azurite), a sulfate (barite), a sulfide (pyrite), and diamond. Two separate studies have been carried out to show the utility of the newly developed analysis system: (1) analysis of a weathering product associated with glass in an SNC meteorite and (2) analysis of different types of FI in an Archean barite. (Authors' abstract)

GIGGENBACH, W.F., 1989, Redox processes governing chemistry of hydrothermal fluids in volcanic systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-553-554.

GIORDANO, T.H., 1989a, Metal-organic complexing in sedimentary basin brines and related ore fluids (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-555-556.

GIORDANO, T.H., 1989b, Anglesite ($PbSO_4$) solubility in acetate solutions: The determination of stability constants for lead acetate complexes at 85°C: Geochim. Cosmochim. Acta, v. 53, p. 359-366.

GIRARD, J-P., DEYNOUX, Max and **NAHON, Daniel**, 1989, Diagenesis of the Upper Proterozoic siliciclastic sediments of the Taoudeni basin (west Africa) and relation to diabase emplacement: J. Sed. Petrol., v. 59, no. 2, p. 233-248. First author at Dept. Geological Sciences, Case Western Reserve Univ., Cleveland, OH 44106.

The predominantly siliciclastic Upper Proterozoic sediments of the Taoudeni basin have been buried to depths of 2.5 to 3 km. In a normal geothermal gradient (25°C/km), maximum burial T of the section studied would be no higher than 100°C. However, detailed petrographic and FI data of sandstones and shales from three areas in Mauritania and Mali along the western side of the basin indicate two major diagenetic events: an earlier low T (<70°C) quartz cementation of the sandstones and a later high T (135-170°C) diagenesis that affected both shales and sandstones. These latter T are too high to have occurred simply in response to burial. The sediments are cut by numerous Jurassic diabase intrusions, which crop out especially commonly in the south and NE. The emplacement of these diabases was related to the opening of the South Atlantic ocean. Contact metamorphism and hydrothermal alteration are visible near intrusive contacts. In western Mali (southern part of basin) where the largest exposed sill in the basin occurs, at 50 to 60 km from any outcropping massive diabase, the late diagenetic paragenesis consists of micas, illite, chlorite, kaolinite, siderite and ankerite. High-T diagenesis is also observed in Adrar of Mauritania (NW part of basin) where outcropping diabases are extremely rare. There, calcite cement is associated with illite and chlorite. FI indicate Tf of 135°C for the ankerite and 170°C for the calcite.

Thus, in spite of a thin sedimentary pile, the Taoudeni basin experienced a high-T diagenesis. We propose that this resulted from circulation of hot fluids, generated during the diabase emplacement, over extensive areas within the basin. (Authors' abstract)

GIULIANI, Gaston and **WEISBROD, Alain**, 1988, Scanning electron microscopy (SEM) and its applications: Determination of solid and daughter minerals in fluid inclusions from some Brazilian emerald deposits: Anais do VII Congresso Latino-Americano de Geologia, Belém, Pará, v. 1, p. 445-457. First author at Dept. Geosci., ORSTOM, Institut Français de Recherche Scientifique pour le développement en Coopération, France, CRPG, Centre de Recherches Pétrographiques et Géochimiques de Nancy, France.

This is the full paper for abstract in Fluid Inclusion Research, v. 21, p. 127-128. (E.R.)

GIZE, A.P. and **BARNES, H.L.**, 1989, Organic processes in Mississippi Valley-type ore genesis (abst.): 28th Int'l Geol. Cong. Abstracts, p. 1-557-558.

GLASMANN, J.R., CLARK, R.A., LARTER, S., BRIEDIS, N.A. and **LUNDEGARD, P.D.**, 1989, Diagenesis and hydrocarbon accumulation, Brent Sandstone (Jurassic), Bergen High area, North Sea: Am. Assoc. Petrol. Geol. Bull., v. 73, no. 11, p. 1341-1360. First author at UNOCAL Science and Technology Div., 376 S. Valencia Blvd., Brea, CA 92621.

Only literature data given. (H.E.B.)

GLASSLEY, W.E., RYERSON, F.J. and **SHAW, H.**, 1989, Chemical changes associated with formation of granulite and migration of complex C-O-H-S fluids, Sri Lanka, *in* D. Bridgwater (ed.), Fluid Movements—Element

Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 39-50.

GLOVER, R.B. and **HEDENQUIST, J.W.**, 1989, A brief history of chemical exploration at Ohaaki-Broadlands, *in* P.R.L. Browne and K. Nicholson, eds., New Zealand Geothermal Workshop, 1989, p. 73-80.

GOEBEL, E.D. and **RAGAN, V.M.**, 1989, Fluid inclusions and sulfur isotopes from MVT deposition and the role of intra-cratonic unconformities (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359. Authors at Dept. Geosciences, Univ. Missouri-KC, Kansas City MO 64110.

The major tectonic structures of the Northern Midcontinent are little changed since formed in the late Paleozoic. They are related genetically and in time with development of the Ouachitas. Positive features (i.e., Ozark Dome, Nemaha Anticline, Central Kansas Uplift) as well as the basins (Forest City, Arkoma) were in place when ores and minor occurrences of MVT mineralization were deposited throughout much of the Paleozoic rocks. Relatively high Th (80-120°+C) in fluid inclusions in the deposits record a widespread heating event(s).

Recent work (Goebel et al., 1988), using Sloss' (1963) inter-regional stratigraphic sequence model of cratonic-wide unconformities, indicates an important role for the unconformities, as fluid/heat conduits. Both fluid inclusion T and S isotopic values appear to reflect hot fluid/heat transfer along regional unconformities. Most of the higher Th in minor occurrences are at the basin/positive feature boundary where cratonic-wide unconformities intersect. Positive $\delta^{34}S$ values from iron sulfides range from +11.2 to +15.5 and are empirically correlated with cratonic-wide unconformities. Whereas elsewhere, values for S from Fe sulfides range from -25.4 to +9.0. Th values for fluid inclusions seem to be less consistent indicators of the passage of fluids. For example, in one long core near Omaha, extending from the Pennsylvanian to Lower Ordovician, the higher Th values (130°+) are on unconformities. However, some of the lowest values (<80°C) are on other unconformities. This may merely be a result of the paucity of data for trace occurrences, or it may reflect the longevity of hydrothermal systems in the Midcontinent. (Authors' abstract)

GOELLNICHT, N.M., **GROVES, D.I.**, **McNAUGHTON, N.J.** and **DIMO, Gorol**, 1989, An epigenetic origin for the Telfer gold deposit, Western Australia, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: Econ. Geol. Monograph 6, The Economic Geol. Publ. Co., p. 151-167. First author at Key Centre for Strategic Mineral Deposits, Dept. Geology, Univ. W. Australia, Nedlands, W. Australia 6009, Australia.

Middle to upper Proterozoic marine sedimentary successions of the Paterson province host Au-Cu mineralization in the quartz sulfide reefs at Telfer, the largest single producing Au mine in Australia during 1987. The origin of Telfer is controversial: most previous models have emphasized the very continuous, stratiform-strata-bound nature of the auriferous Middle Vale reef and postulated a syngenetic exhalative origin. However, recent deeper mining and drilling of hypogene ore provides evidence that Telfer is an epigenetic deposit.

A number of granitoids intruded the middle to upper Proterozoic succession late in its tectono-magmatic history. The Pb isotope sulfide data are best explained by derivation of most of the Pb from the host rock (or basinal brines), with some contribution from a magmatic source such as the Mount Crofton Granite. FI from quartz in veins and the Middle Vale reef contain very complex saline and CO_2-rich fluids that homogenize between 225° and 440°C: salinities range between 21 and 54 eq. wt % NaCl. Dms include halite, Fe-bearing calcite, sylvite(?), and dawsonite. FI data are indicative of mixing of hot, very high salinity (magmatic) fluids with cooler, lower salinity (basinal or meteoric) waters with liberation of CO_2 during replacement of carbonate host rocks.

Telfer is reinterpreted to be an epigenetic vein-hosted replacement deposit in which Au mineralization was controlled by both structure and composition of the host rocks. Hot, saline fluids introduced Cu and Au during late deformation and granitoid emplacement, but the source of the Au is not yet established. (From authors' abstract by H.E.B.)

GOFF, F. and **SHEVENELL, L.**, 1989, Deuterium and oxygen-18 relations among meteoric waters, "new" hot spring waters, fumarole condensates, and volcanic rocks, Mount St. Helens, Washington (abst.): Eos, v. 70, p. 495.

GOLDFARB, R.J., 1989, Genesis of lode gold deposits of the southern Alaskan cordillera: PhD dissertation, Univ. Colorado. Author at U.S. Geol. Survey, Denver Federal Center, MS 973, Denver, CO 80225.

Mesothermal Au-bearing quartz veins are widespread throughout the allochthonous tectonostratigraphic terranes of southern Alaska. The host terranes are largely composed of complexly deformed, clastic metasedimentary rocks, with lesser felsic to mafic volcanic rocks, and post-accretionary, calc-alkaline intrusive bodies. Auriferous veins, and related placers, are restricted to medium grade metamorphic sequences. The veins are found in both small shear zones and tensile fractures, and along major crustal lineaments. Au deposits were studied within the Port Valdez, Port Wells, Girdwood, Moose Pass, and Hope-Sunrise districts in south-central Alaska, and in the Chichagof district and along the Juneau Au belt in southeastern Alaska. Pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, and (or) chalcopyrite occur, along with Au, in these systems. Wall rock carbonatization, sulfidization, silicification, and less commonly, sericitization or albitization are consistent features within all of the Au districts.

Fluid inclusion examination by microthermometry, laser Raman spectroscopy, and mass spectrometry, along with stable isotope studies, constrained ore fluid sources and conditions of ore deposition. Th for ore-related fluid inclusions ranged between 150-310°C, with the majority between 210-280°C. Pt are estimated to be at least 1-2 kb for all deposits, corresponding to depths of at least 3.5-7 km. Most ore solutions, trapped in the one-phase field, contained less than 5 eq. wt % NaCl and consisted of at least 90 mole % H_2O, plus lesser CO_2, CH_4, N_2, and H_2S. The ore fluids at the Alaska-Juneau deposit, however, contained approximately 50 mole % CO_2 and showed unequivocal evidence of fluid immiscibility. Calculated isotopic compositions for ore fluids at all deposits ranged from 6-10‰ for $\delta^{18}O$ and -20 to -30‰ for δD, consistent with metamorphic water. The data are incompatible with deeply circulating meteoric fluids, unless enormous exchange occurred between the hydrothermal fluids and the metasedimentary pile.

Absolute and relative age relationships indicate Au genesis during the Eocene and Oligocene throughout much of southern Alaska. The ore solutions were derived from devolatilization of dominantly pelitic, subducted crust. These fluids migrated upward to higher, retrograding crustal levels, that were undergoing rapid uplift, prior to precipitation due to oxidation and sulfidization reactions. (Author's abstract)

GOLDFARB, R.J., LEACH, D.L., ROSE, S.C. and **LANDIS, G.P.**, 1989, Fluid inclusion geochemistry of gold-bearing quartz veins of the Juneau gold belt, southeastern Alaska: Implications for ore genesis, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 363-375. First author at U.S. Geological Survey, Box 25046, MS 973, Federal Center, Denver, CO 80225.

Microthermometry, laser Raman spectroscopy, and mass spectrometry were used to study FI in Au-bearing quartz veins from the mines of the Juneau Au belt. Unmixing of a CO_2-rich parent fluid led to the contemporaneous trapping of H_2O-dominant and CO_2-dominant inclusions during Au deposition at the Alaska-Juneau, Reagan, and Ibex mines. Ore fluids at all other mines were trapped as homogeneous, H_2O-dominant fluids, with less than 10 mole % CO_2. Both N_2 and CH_4 are present at the % level within the volatile phases in all deposits; H_2S makes up one-third of the volatile phase and 2 mole % of the total ore fluids at the Sumdum Chief mine. The ore fluids contained less than 5 eq. wt % NaCl. Au deposition occurred at $T > 250°C$ and at depths of at least 5 km. The Au-forming fluids are believed to have been derived from devolatilization reactions associated with prograde metamorphism of dominantly pelitic, subducted crust. (Authors' abstract)

GOLDSMITH, J.R. and **PETERSON, J.W.**, 1989, Water-saturated melting behavior of microcline and sanidine (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A157.

GOLDSTEIN, R.H., ANDERSON, J.E. and STEPHENS, B.P., 1989, Importance of one-phase all-liquid fluid inclusions in calcite and dolomite (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 26. Authors at Univ. Kansas, Dept. Geol., Lawrence, KS 66045.

Diagenetic calcite and dolomite commonly precipitate at <45°C. Under these conditions, homogeneous entrapment results in a population of one-phase all-liquid inclusions. As low-T diagenetic phases are subjected to deepening burial and increasing T, P within the all-liquid inclusions increase. For some inclusions, the overpressure either causes inclusions to stretch their walls or decrepitate and refill with burial fluids. The depth at which this reequilibration occurs depends on size and shape of the inclusion, its position within the crystal, local strength of the crystal, amount of overheating, and surrounding P. As these variables may affect each FI differently, during overheating of low-T FI, some may reequilibrate and others may remain intact. If one finds one-phase all-liquid and two-phase vapor liquid inclusions in a growth zone of calcite or dolomite, the one-phase FI indicate cement precipitation at low T and the two-phase inclusions may have formed through reequilibration. Petrographic criteria should be employed to eliminate variable phase ratios caused by necking down or inhomogeneous entrapment, and should identify [i.e., verify?] that one-phase inclusions are as large as some of the two-phase inclusions. Three case studies show that one-phase all-liquid FI provide the best record to original salinity and low T of precipitation.

Calcite cement from New Mexico, precipitated during pre-Pennsylvanian subaerial exposure, contains abundant P FI. Petrographic, stable isotope, and trace element data indicate precipitation from fresh water at earth-surface T. One-phase all-liquid and two-phase FI are present. Of the two-phase inclusions, 74% contain concentrated brines apparently leaked in during burial reequilibration, and 26% contain fresh water. All of the one-phase all-liquid FI measured contained fresh water. The one-phase all-liquid inclusions contain the most reliable data on conditions of precipitation.

An early generation of calcite cement from the Pennsylvanian Lansing-Kansas City groups of the subsurface of northwestern Kansas contains P one-phase all-liquid and two-phase FI. Later cement generations contain only two-phase FI. For the early generation, freezing data of one-phase inclusions suggests precipitation from a brine of ~22-24 wt % NaCl eq., whereas data for two-phase inclusions cover a wider range from ~45°C from a brine of ~22-24 wt % NaCl eq.

P FI in dolomite from the mid-Cretaceous Tamabra fm of central Mexico are one-phase all-liquid and two-phase. One-phase freezing data indicate a salinity of ~16-20 wt % NaCl eq. Two-phase inclusions range from ~10-21 wt % NaCl eq. Later two-phase S inclusions yield salinities from ~0-11 wt % NaCl eq. The salinities of the S inclusions are similar to some of the two-phase inclusions in the dolomite, whereas the one-phase inclusions have a distinct salinity range. Some of the P FI in dolomite have reequilibrated with the later, lower salinity fluids. The dolomite precipitated from a brine of about 16-20 wt % NaCl eq., below ~45°C.

P, one-phase all-liquid FI in calcite and dolomite indicate low T of precipitation and provide the best record of salinity of the precipitating fluids. Two-phase inclusions in the same population may provide a record of reequilibration rather than precipitation. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p. 141. (E.R.)

GONCHARENKO, O.P. and KOROBOV, A.D., 1988, Temperature conditions of calcite formation from hydrothermal solutions from fluid inclusion studies (southern end of Kamchatka Peninsula): Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 58 (in Russian). Authors at Sci.-Research Inst. Geology at the Saratov State Univ., Saratov, U.S.S.R.

Inclusions in calcite were studied for determination of T gradients in the Pauzhetskoe hydrothermal field. Samples were taken from drill cores from this field and from the region of Kuril'skoe Lake. The calcite forms veinlets of three varieties. Inclusions are mainly two-phase (G consists of 5-8 vol % H_2O vapor). G + L + halite inclusions, with 8-10 vol % gas and 10-15 vol % NaCl, are rare. Th and Td are practically the same. For the Pauzhetskoe field the following T intervals were found: 70-100°C (calcite I [although the Russian text gives here probably erroneously "calcite III," A.K.]), 100-200°C (calcite II), 200-300°C (calcite III). At the area of Kuril'skoe Lake, calcite from veinlets yielded T 100-200°C (calcite II) and 200-300°C (calcite III). This indicates the influx of hydrothermal solutions in several stages. (Authors' abstract translated by A.K.)

GONG, Wenshu and **OU, Zhenwu**, 1989, The characteristics and origin of the Qiling granite: Dizhi Lunp'ing Geol. Rev., v. 35, (5), p. 448-455 (in Chinese).

Indexed under Fl. (E.R.)

GONZALEZ, C.M., 1989, Fluid inclusion study of the vein mineralization in the VC-2A corehole, Valles Caldera, New Mexico: MS thesis, Univ. California, Riverside, CA.

Valles caldera corehole VC-2A was drilled into the acid sulfate hot spring system of Sulphur Springs, New Mexico. The borehole was advanced 528 m through quartz-rich welded tuffs and volcaniclastic sandstones which contain S vein mineralization of quartz, pyrite, calcite, fluorite, molybdenite, and rhodocrosite. Although the system penetrated by VC-2A is now vapor-dominated, textures of the S mineralization indicate that a liquid-dominated system was present at one time. It is thought that the system was boiling at the time of mineralization.

This study of fluid inclusions in vein minerals in the VC-2A core is designed to gain information on the conditions under which the mineralization occurred. Fluid inclusions from quartz and fluorite which occur between ~30 and 200 m depth were generally liquid-dominated and had a salinity of <0.53 wt % NaCl. Th of P inclusions in quartz were ~23°C higher than S inclusions, indicating that the system was cooling subsequent to quartz deposition. Th of P inclusions in quartz were also higher than those in fluorite by ~35°C. This suggests that the fluorite studied was deposited after the quartz. In order for these minerals to have been deposited at the T revealed by Th, they had to have been at hydrostatic P corresponding to depths of ~100 m, as restricted by the boiling point curve. This depth is ~175 m greater than the present depth at which some of these minerals occur and has been accounted for in the literature by either erosion or a caldera lake.

One calcite sample from 522 m was studied. This sample was separated from the nearest quartz and fluorite studied by ~300 m of tightly sealed rock. The fluid inclusions in the calcite were liquid-dominated and had Tm ice which indicated a salinity of 1.73 wt % NaCl, somewhat greater than that of the quartz and fluorite inclusions. Th of inclusions in the calcite were also higher. P inclusions were ~100°C higher and S were about ~50°C to 75°C higher than for the inclusions in the shallower quartz and fluorite samples. The higher T and greater salinity may indicate that the calcite mineralized from fluids different than those higher in the section. Alternatively, it may be that as the fluids ascended, they were slightly cooled and diluted by meteoric water entering above the tightly sealed rock. (Author's abstract)

GONZALEZ-PARTIDA, E., GOMEZ, D.N. and **BARRAGAN-REYES, R.M.**, 1989, Detailed study of fluid inclusions in the active hydrothermal system of Los Azufres geothermal field, Michoacan: Geotermia., v. 5, (1), p. 126-152 (in Spanish).

GOODARZI, F. and **NORFORD, B.S.**, 1989, Variation of graptolite reflectance with depth of burial: Inst. J. Coal Geol., v. 11, p. 127-141.

GORBACHEV, N.S., 1989, Fluid-magma interaction in sulfide-silicate systems: Moscow, Nauka Press, 127 pp. (in Russian).

An extensive review of volatiles in magmas, experimental studies of silicate melts with volatiles and sulfides, and a discussion of application to problems of magmatic differentiation. (E.R.)

GORYAINOV, I.N., GRAMBERT, I.S., SMEKALOV, A.S. and **TIKHOMIROV, Yu.V.**, 1989, The problem of regularities of distribution of deep-water sulfide mineralization in the ocean (the hypothesis of "mantle spicules"): Doklady Akad. Nauk SSSR, v. 306, no. 5, p. 1185-1188 (in Russian).

Silica aggregates from limestones of the Marquise Island series of Marcus-Necker Seamount yielded Td up to 500°C. (A.K.)

GORZAWSKI, Hendrik, 1989, Isotopic, geochemical, and petrographic characterization of the diagenetic evolution in carbonate-hosted stratabound Zn-Pb-(F-Ba) deposits (with a comparison of Croix de Pallières/France, San Vicente/Peru, and other localities): Heidelberger Geowiss. Abh., v. 28, 250 pp.

Presents fluid inclusion data for the Croix de Pallières Zn-Pb district, France, and the San Vicente Zn-Pb mine, Peru. (H.E.B.)

GRAHAM, U.M. and **OHMOTO, Hiroshi,** 1989, Hydrothermal experiments on the roles of pyrrhotite and anhydrite in the formation of pyrite (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A104.

GRAMENITSKIY, Ye.N., SHCHEKINA, T.I. and **MITREYKINA, O.B.,** 1989, Liquidus aluminosilicate-alkalifluoride immiscibility (experimental data): Doklady Akad. Nauk SSSR, v. 306, no. 6, p. 1446-1450 (in Russian). Authors at Moscow State Univ., USSR.

The experiments were performed at 800 and 1000°C, 1 kbar in the system: alkali feldspars-K_2SiF_6-water, fluorine content from 4 to 20 wt %, water from 2 to 14 wt %, various Na/K ratios. In the quenching products two glasses were observed: alkali-aluminofluoride in aluminosilicate matrix. Immiscible melts, similar to those obtained in experiments at 800°C, were found in inclusions in orbicular granites of the Kent massif, Central Kazakhstan. (A.K.)

GRANOVSKIY, A.G. and **GRANOVSKAYA, N.V.,** 1988, Heterogeneity of the hydrothermal solutions during formation of barite, polymetal and rare-metal ore mineralization: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 15 (in Russian). Authors at Rostov State Univ., Rostov-on-Don, U.S.S.R.

A general characterization. (A.K.)

GRANT, J.A. and **LINDSLEY, D.H.,** 1989, Melting of quartz-K feldspar-cordierite under dry, water-, and carbon dioxide-bearing conditions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A239.

GRATZ, A.J., BIRD, P. and **QUIRO, G.B.,** 1989, Surface kinetics, textures, and dynamics of quartz dissolution under hydrothermal conditions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A44-45.

GRAVES, M.C., RUFFMAN, A. and **HEIN, F.J.,** 1989, Economic geology and development of the Jubilee Pb-Zn Deposit, Cape Breton Island, Nova Scotia (abst.): Atlantic Geology, v. 25, p. 159-160. First author at Cuesta Research Ltd., 154 Victoria Road, Dartmouth, Nova Scotia B3A 1V8, Canada.

Mineralization occurs in thin basal Windsor limestone beneath thick evaporites. The host limestone breccia is better developed, thicker, and more mineralized in a narrow zone parallel to the Jubilee Fault. This growth fault has controlled local sedimentation as well as a fluid migration history. A model of ore formation associated with growth faults over thick Horton clastics opens much of the Horton/Windsor surface for potential mineralization. Post-ore karst controls the present geomorphology and the distribution of the gypsum being mined above the deposit.

Ore minerals are sphalerite and galena. Though Ag is cited in reports on the deposit, no assays have shown detectable Ag. Chalcopyrite is common in the footwall clastics but only in trace amounts. The paragenetic sequence is pyrite-sphalerite-galena-barite with calcite throughout. Hydrocarbons are common in present-day porosity and in ore-stage solid and fluid inclusions. (From authors' abstract by E.R.)

GRAY, R.T., LARROUSSE, M.F. and WILCOX, W.R., 1988, Diffusional decay of striations: J. Crystal Growth, v. 92, p. 530-542. First author at Dept. Chemical Engineering and Center for Advanced Materials Processing, Clarkson Univ., Potsdam, NY 13676.

During crystal growth from melts and solutions, compositional striations in the bulk crystal parallel to the growth surface usually result from fluctuations in the growth rate and/or the flow of the growth fluid. This paper presents a one-dimensional analysis of the effect of solid-state diffusion on growth striations. (From authors' abstract by E.R.)

GREGG, J.M. and SHELTON, K.L., 1989, Geochemical and petrographic evidence for fluid sources and pathways during dolomitization and lead-zinc mineralization in southeast Missouri: A review: Carbonates and Evaporites, v. 4, no. 2, p. 153-175. First author at Dept. Geology and Geophysics, Univ. Missouri-Rolla, Rolla, MO 65401.

Fluid inclusions in sphalerites and dolomites throughout southern Missouri and northern Arkansas indicate that mineralizing basinal brines were very saline (~16 wt % eq. NaCl) and warm (~80° to 150°C). The lack of discernible thermal gradients in fluid inclusion T from regionally extensive epigenetic dolomites and the range of fluid inclusion salinities indicate that more than one basin fluid was involved in dolomitization and associated Pb-Zn ore deposition. Taken as a whole, available geochemical and petrographic evidence indicate that dolomitization and Pb-Zn mineralization in southeast Missouri were the result of a more complex, multiple-basin fluid interaction than previously recognized. (From authors' abstract by E.R.)

GREGORY, R.T., CRISS, R.E. and TAYLOR, H.P., Jr., 1989, Oxygen isotope exchange kinetics of mineral pairs in closed and open systems: Applications to problems of hydrothermal alteration of igneous rocks and Precambrian iron formations: Chem. Geol., v. 75, p. 1-42.

GREGORY, R.T., GRAY, D.R., CRISS, R.E. and DURNEY, D.W., 1989, Mineral-fluid exchange kinetics: Oxygen isotopic signatures of quartz veins in slate belts (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A85.

GRICHUK, D.V., SUSHCHEVSKAYA, N.M., VASYUTA, Yu.V. and KONONKOVA, N.N., 1988, On the role of magmatic fluids in formation of chemical composition of hydrothermal waters of mid-oceanic ridges: Geokhimiya, no. 12, p. 1741-1750 (in Russian, English abstract; translated in Geochem. Int'l, v. 26, no. 7, p. 50-xy, 1989). First author at Moscow State Univ., Moscow, U.S.S.R.

It is suggested to use the content of CO_2, which is the main component of magmatic fluids associated with tholeiitic basalts of Mid-Oceanic Ridges, for estimation of the percentage of magmatic fluids in the composition of hydrothermal fluids. The maximum estimate of magmatic H_2O percentage was found by analyzing the H_2O/CO_2 ratio in quenched basalt glass samples (Table). For more accurate estimation it is necessary to take into account that fluid separating from the melt is relatively enriched in CO_2. Moreover, some of the CO_2 may come into the hydrothermal solution from other sources (including exogenic ones). For the most studied hydrothermal system at 21°N East Pacific Rise, the calculation shows the percentage of magmatic water cannot be more than 0.38% here and is probably only 0.0005% of the total mass of hydrothermal solution. Therefore, the supply of the ore components into hydrotherms by magmatic fluids seems to be insignificant. (Abstract by T. Sushchevskaya)

(Continued on next page)

H_2O and CO_2 contents in tholeiitic glasses.

	Mid-Atlantic Ridge															Ar. In. R.	East Pacific Rise	
Sample	421	43/1	43/7	43/8	40/1	40/2	19/2	26/11a	26/13a	25/1	25/4	25/7	25/11	5-35/6	mean*	2173/16	SRII-DR3	mean*
Compon.								Thermal decrepitation of glasses										
H_2O	1090	6400	2700	4900	670	980	630	269	1700	2700	2600	3000	2200	2070	2010	2160	3870	1200
CO_2	79	124	139	118	61	365	59	104	88	310	449	112	139	82	1320	76	90	1630
CH_4	1.28	1.53	4.4	0.62	1.28	3.5	1.9	0.01	0.82	0.12	0.89	6.6	2.11	2.91	-	2.75	0.59	20
H_2O/CO_2	34	126	48	100	27	6.6	26	6.3	47	21	14.3	65	38	61	3.7	70	105	1.8
								Crushing of glasses										
H_2O	n.d.	n.d.	n.d.	11	n.d.	n.d.	n.d.	n.d.	2	3	n.d.	n.d.	n.d.	4	-	n.d.	n.d.	-
CO_2	236	1.31	17.1	890	2.0	1.6	22	43	82	147	80	49	19.6	326	-	472	43	-
H_2O/CO_2	-	-	-	0.03	-	-	-	-	0.059	0.016	-	-	-	0.03	-	-	-	-

*Average data from Byers et al. (1986).

TOR — tholeiites of Ocean Ridge. TOR-1 D < Do (#421 only); all others TOR-2 D > DO DO = 258.09 for glasses (Suschevskaya et al., 1983).

$D = 16.53\ Na_2O + 16.19\ TiO_2 + 3.114\ SiO_2 + 2.93\ MgO + 1.45\ CaO + 0.92\ Al_2O_3 - 32.94\ K_2O - 1.46\ FeO$. [Note: Original gives chemical analyses of each of the basalts for 10 constituents. (E.R.)]

GRIMAUD, D., ISHIBASHI, J., AUZENDE, J.M. and **URABE, T.**, 1989, The chemistry of the hot springs at 17°S on the North Fiji Basin axis (SW Pacific) (abst.): Eos, v. 70, p. 1398.

GRISHINA, S.N., 1988, Inclusions in halite from a contact metamorphism zone of the Siberian platform, *in* N.V. Sobolev, ed., Thermobarogeochemical Studies of Processes of Mineral Formation: Novosibirsk, Nauka Publ. House; pub. of Inst. Geol. and Geophysics no. 733, ISBN 5-02-028807-1, p. 200-206 (in Russian; see Translations).

GRISHINA, S., and **DUBESSY, J.**, 1989a, Native sulphur and CO_2-bearing inclusions in salts of the Bakhtinsky Siberian Platform, USSR (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 38. First author at Inst. Geol. and Geophys., 630090, Novosibirsk, USSR.

CO_2-S_8-bearing inclusions were found in Cambrian salts Lena-Tunguska gas-oil-bearing province of the Siberian Platform, which were recrystallized during thermal metamorphism caused by dolerite intrusion. The inclusions which we have studied in evaporitic rocks, as opposed to those of the same type described elsewhere, are water-depleted and contain various ratios of CO_2 and S_8 ranging from essentially CO_2 inclusions with a S impurity to S inclusions with a CO_2 bubble. Microthermometry and Raman microspectrometry were used to study four types of inclusions: (i) sulphur solid inclusions; (ii) CO_2-bearing inclusions without solid phases; (iii) CO_2-inclusions with crystalline or amorphous sulphur; and (iv) sulphur dominant inclusions.

At room T, CO_2-bearing inclusions consist of liquid CO_2-H_2S fluid with Tm CO_2 between -57 and -58°C. Liquid phase Th values were found to be between -18 and -23°C, unusually low for evaporites. The T range of S dissolution in CO_2-bearing inclusions has been determined as being between 60 and 300°C.

Salt samples were taken from deep wells of the Bakhtinsky platform megaprojection, where pools of free CO_2 gas have been discovered. To understand the nature of the gas pools, we have studied relicts of the fossil fluids that migrated through permeable rocks during magmatism, the composition of the fluids was determined by interaction in the system: magma/initial rock-forming minerals/water and the initial liquid and gaseous hydrocarbons. This also provides a good opportunity to study the fluid associated with thermal metamorphism of dolomite and evaporite. The fluid chemistry is very unusual since it seems to indicate a heterogeneous trapping of a CO_2 fluid and liquid S at T higher than 120°C. (Authors' abstract)

See also next item. (E.R.)

GRISHINA, S.N., and **DUBESSY, J.**, 1989b, Native sulfur in carbon dioxide-containing inclusions: Geokhimiya 1989, no. 4, p. 525-531 (in Russian; translated in Geochem. Int'l, v. 26, no. 11, p. 51-57). First author at Inst. Geol. Geofiz. Novosibirsk, U.S.S.R.

See previous item and Fluid Inclusion Research, v. 21, p. 467-472. (E.R.)

GROEN, J.C., BODNAR, R.J. and CAMPBELL, T.J., 1989, Fluid inclusions in the Homestake Iron Formation of the northern Black Hills of South Dakota and their relationship to metamorphism (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 27. First author at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

Quartz from 5 different sample localities in the Homestake Formation contains several generations of FI exhibiting a wide variety of compositions. Early, negative crystal shaped inclusions up to 70 µm in maximum dimension are CH_4-rich or CO_2-rich and were probably formed near peak metamorphic conditions. Greenschist grade rocks have only been observed to contain CH_4-rich inclusions whereas amphibolite grade rocks tend to contain both CH_4-rich and CO_2-rich inclusions in varying proportions. Later, irregularly shaped aqueous inclusions up to 250 µm in maximum dimension are of variable salinity. All inclusions occur along healed fracture traces and are probably S or PS. FI of intermediate composition are frequently found near the intersections of fractures.

Laser Raman microprobe analyses of the CH_4-rich inclusions indicate the presence of CH_4, CO_2 and N_2. Microthermometric data on these inclusions show a complex series of phase transformations consistent with known phase equilibria relations in the CO_2-$CH_4 \pm N_2$ system. The observed phase behavior suggests a composition of $\sim 0.92CH_4$-$0.05CO_2$-$0.03N_2$. Isochores for these inclusions were calculated using a MRK equation of state. Assuming these earliest inclusions formed at greenschist metamorphic T, the calculated isochores yield trapping P in the range of 160 to 240 bars, suggesting reequilibration of the inclusions during uplift. Microthermometric data on the CO_2-H_2O inclusions suggest no appreciable quantities of other gases. Tm clathrate yield a salinity of ~4.5 wt %. The later, aqueous inclusions have a broad range of salinities from ~3 wt % to >30 wt %. (Authors' abstract)

GRUNDMANN, G. and MORTEANI, G., 1989, Emerald mineralization during regional metamorphism: The Habachtal (Austria) and Leydsdorp (Transvaal, South Africa) deposits: Econ. Geol., v. 84, p. 1835-1849. Authors at Lehrstuhl für Angewandte Mineralogie und Geochemie, Technische Universität München, Lichtenbergstrasse 4, D-8046 Garching, F.R.G.

Classic schist-hosted emerald deposits are generally attributed to interaction between invading pegmatitic magma or vapor phases with preexisting metasediments, metavolcanics, and/or ultrabasic rocks. Detailed studies of the Habachtal (Austria) and Leydsdorp (South Africa) emerald deposits indicate that the emerald formation was not due to a single-stage contact metamorphism at the border zone of magmatic intrusive bodies. On the contrary, the emeralds are found in metasomatic zones (blackwall zones) associated with ultramafic bodies formed by syn- to post-tectonic reactions during low-grade regional metamorphism. These reactions occur at the contact of preexisting beryl- and phenakite-bearing pegmatites and albite pegmatoids with biotite-talc and actinolite schists (Leydsdorp), or at the contact of Be-rich garnet-mica schists and biotite-plagioclase-gneisses with serpentinites and talc-schists (Habachtal).

The high Mg and Cr contents—mainly in the rims of the emeralds—reflect their formation in an increasingly Mg- and Cr-rich environment. Microthermometric studies of fluid inclusions in the emeralds of both deposits suggest that they formed from an H_2O-CO_2 mixed fluid phase, with a salinity of 1 to 9 eq. wt % NaCl and Th ~300°C. Mass balance and geochemical analyses suggest that the transformation of serpentinites and Be-rich country rocks into blackwall zones liberates significant amounts of Be and enables the formation of emerald in the presence of Cr. Due to unfavorable growth conditions during regional metamorphism, the extent of emerald mineralization never exceeds that of pegmatites. (From authors' abstract by E.R.)

GRÜNER, F., HATZL, T. and MORTEANI, G., 1989, Gold in amphibolites of the Münchberg gneiss massif, northeastern Bavaria, West Germany (abst.): Terra abstracts, v. 1, p. 28-29.

Free Au can be found in quartz, predominantly along grain boundaries and in paragenesis with pyrite, chalcopyrite, bornite and subordinately molybdenite, Au-, Ag-Hg-tellurides and bismuthinides. Fluid inclusion data from quartz show a wide range in Th between 160°C and 350°C. The salinity of the fluids varies between 2.4% NaCl eq. up to 28.4% NaCl eq. Tm indicate fluids bearing NaCl together with other chlorides such as $CaCl_2$, $MgCl_2$ and KCl. (From authors' abstract by E.R.)

GUAN, Guangyue, ed., 1989, Proceedings of International Symposium on Gold Geology and Exploration (ISGGE), Shenyang, June 26-30, 842 p. Published by Northeast Univ. Technology, Shenyang, ISBN 7-81006-168-2/TD.8.

This volume of 240 abstracts and short papers, including many with inclusion data, was received too late for inclusion here, except for one (Kozlowski and Metz). The remainder will be in Volume 23. A warning note is in order: Numerous typographical errors were introduced into this volume during retyping in P.R.C. (A.K.)

GUHA, Jayanta, LU, H.-Z. and **GAGNON, Michel**, 1989, Analysis of gas compositions of fluid inclusions by "solid probe" mass spectrometry (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 28. First author at Sci. de la Terre, Univ. Quebec Chicoutimi, Chicoutimi, Qc., Canada, G7H 2B1.

Mass spectrometric methods coupled with gas chromatography have been used by several workers to analyze gas compositions in FI. Most of the methods are unable to distinguish the output from a single generation of inclusions. This information can be vital to the understanding of the evolution of fluids in a sample containing several generations of inclusions. To overcome this problem a mass spectrometer has been used which has a probe positioned directly in the ionization chamber. This probe holds a solid sample which can be heated continuously or stepwise up to 900°C. The decrepitated gas is released directly into the spectrometer source thus reducing contamination. Routine petrographic analysis and heating/freezing stage work first determine the different generations of inclusions and their Td. Then tiny pieces of the doubly polished section can be cut and introduced into the solid probe and the heating programmed accordingly. Slower heating rates may be chosen around critical T values, permitting pinpointing the "bursts."

Several tests were run to establish the minimum quantity of sample required for detection, types of gas, the suitability of different host minerals and the calibration to determine ratios quantitatively. The results show that the weight of the sample can be as low as 0.0003 gm. The principal gas species which can be analyzed are CO_2, CO-N_2, H_2, H_2O, H_2S and nearly all light hydrocarbons. Different host minerals such as quartz, fluorite and barite pose no problem. Moreover, the small amounts of samples required enables the analysis of sulfides associated with the host transparent mineral. Reproducible ratios of gases have been obtained using either a pulse height area integrator or calibrations from known mixtures of gases.

Tests on samples from Archaean Au deposits indicate the potential of this method, not only to detect the presence of different gases in the fluid, but also to determine gas ratios (CO_2-H_2O in this case) in different generations of inclusions rapidly and fairly accurately. An important advantage of this method is the capability to match the presence of gases in inclusions in quartz with those in associated sulfides thereby confirming that the FI in quartz represent the mineralizing phase indeed. These tests indicate that this method can be useful for both reconnaissance and detailed investigation where gas compositions of FI are important for the understanding of fluid evolution processes. (Authors' abstract)

GUILHAUMOU, N., SZYDLOWSKI, N. and **PRADIER, B.**, 1989, Characterization of hydrocarbon fluid inclusions by infrared and fluorescence microspectrometry (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 40. First author at Lab. Géol. de l'Ecole normale supérieure, U.R.A. 1316, 24 rue Lhomond - 75005 Paris, France.

Liquid hydrocarbon-bearing FI have often been described associated with petroleum occurrences and diagenetic sediments. Because of their strong fluorescence under a laser beam (Raman spectroscopy using 514.5 and 488.0 nm wavelength), their individual composition has been poorly investigated until now.

Infrared microspectrometry allows exact characterization by absorption of aliphatic and aromatic hydrocarbons as well as H_2O, CO_2, CH_4 and associated solid phases, on FI >20 µm. Semi-quantitative analyses have been made on gaseous and liquid phases. In this way CH_3/CH_2 and CO_2/CH_4 ratios have been accurately determined.

Fluorescence microspectrometry allows precise measurement of the fluorescence emission spectrum of chromophores bearing organic phases) essentially aromatic hydrocarbons in FI >10 µm). Such spectra are a function of both the gross composition of the trapped oil and of its thermal history. In this way, fluorescence parameters can be used, at least, to make accurate distinction between different generations of oil inclusions in a mineral.

Both these methods lead to the in-situ characterization of fluid hydrocarbon inclusions, making possible an accurate and quantifiable distinction between different oil generations trapped during mineral growth. Using the data obtained, a relationship can be then established between different stages of mineral growth, and the different thermal histories of the sediments and oil migration events. (Authors' abstract)

GUILHAUMOU, N., TOURAY, J.-C., BENY, C. and DARDENNE, M., 1989, Methane-rich fluid inclusions in gold-bearing quartz as illustrated at Pontal Goias, Brazil (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 39. First author at Lab. Géol. de l'Ecole Normale Supérieure, U.R.A. 1316, 24 rue Lhomond 75005 Paris, France.

The Pontal Au deposit is a small, unusual Au deposit (about 1 t reserves) hosted by a quartz lens which is conformable with the host biotitic gneisses, but crosscut by pegmatitic dikes. FI from the auriferous quartz have been studied by microthermometry and Raman microprobe. Two main types (early and late) have been distinguished for their habit, distribution and spatial relationship with Au microparticles. Type IA are P multiphase large sized (100 to 200 µm) inclusions with Th ($V + L \rightarrow L$) between 350-450°C. They contain siderite (or ankerite) and graphite-like microcrystals as dp. Commonly associated with these inclusions are tiny (50 to 100 µm) solid inclusions of rutile and biotite. In most of these inclusions only CH_4 has been detected in the vapor phase. However, some noticeable exceptions were observed (CO_2/CH_4 ratio near 0.85). Type IB inclusions are small (<10 µm) CH_4-(H_2O) inclusions heterogeneously trapped and directly associated with Au particles. Type II inclusions are later than the Au and occur disseminated along trails that crosscut quartz grain boundaries. They are usually characterized by the presence of nahcolite dxls. Most of them contain only CH_4 in the gaseous phase, but nahcolite-bearing inclusions have been found with high CO_2/CH_4 ratio. Th scatter from 150 to 300°C.

The observed large variation of the CO_2/CH_4 ratio in similar inclusions (same trapped and dp) raises the problem of kinetically controlled redox reactions occurring with FI. (Authors' abstract)

GUILLOT, C. and MOINE, B., 1989, Relationships between N_2 in fluid inclusions and NH_4^+ in rocks (and micas) in the Dôme de Montredon - Montagne Noire, France (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 41. Authors at Lab. de min., UA67 CNRS, Univ. Paul Sabatier, 39 Allées Jules Guesde, 31400 Toulouse, France.

The Dôme de Montredon is an Hercynian structure involving an othrogneissic core overlain by a metasedimentary Lower Cambrian series. An upper epizonal metamorphism and hydrothermal alteration were induced by a deep-seated granitic stock. Tourmaline and feldspar crystallization after micas, coupled with W mineralization, were a result of hydrothermal activity.

The FI study has been undertaken mainly on synmetamorphic quartz lenses within the whole lithologic sequence. The main results are: (i) H_2O-CO_2-CH_4 fluids with low salinity are ubiquitous; (ii) N_2, which comprises 5 to 35 mole % of the gas (Raman microprobe by C. Beny), is present in the K_2b black-schists (up to 7% organic carbon) only; (iii) away from the Dôme, N_2 is absent in the FI of the lower epizonal and unaltered K_2b formation.

N_2 analyses were obtained by CHN analyzer and IR spectrometry on whole-rock and micas (+ clay minerals). Chemical analyses (by J. Ben. H. Jansen, Utrecht) will be used in order to calibrate these data. The black-schists are by far the most N_2-rich formation. The N_2 is present as NH_4 in the micas or illites. The carbonaceous material is N_2-free. The N_2 content of the K_2b formation is lower within the Dôme than away from it. The lowest N_2 contents are observed in the host rocks of the stratiform scheelite mineralization (l'Hom-haut) where the metamorphic/hydrothermal alteration was intense (pyroxene and biotite-bearing schists). The fluids inclusions within the same rocks exhibit the highest N_2 content.

These results strongly suggest that N_2 in FI was produced by the metamorphic/hydrothermal breakdown of NH_4^+-bearing micas. The primary source of N_2 was organic matter. This approach is now being applied to the Dôme de l'Agout where a similar series with abundant orthogneisses was altered by high grade metamorphism and anatexis. (Authors' abstract)

GUILLOT, C., MOINE, B. and BENY, C., 1989, Microthermometry and Raman microprobe analyses of the fluid inclusions in the Dôme de Montredon-Montagne Noire, France: Relationships between nitrogen in fluid inclusions and ammonium in whole-rocks and micas (abst.) Symposium GEORAMAN 89, Toulouse, France, 17-19 May 1989, Abstracts (unpaginated). First author at Laboratoire de Minéralogie, UA67 CNRS, Univ. Paul Sabatier, 39 Allées Jules Guesde, 31400 Toulouse, France.

The Hercynian structure of the Dôme de Montredon involves an orthogneissic core overlain by a metasedimentary Lower Cambrian series. A deep-seated granitic stock induced metamorphism in the upper epizone and fluid flow from which W occurrences were issued.

The fluid inclusions study has been performed mainly on syn-metamorphic quartz lenses within the whole Montredon lithologic sequence. The main results are: (1) H_2O-CO_2-CH_4 fluids with low to medium salinity are present in variable amounts ($H_2O > 90$ mole %) all over the Dôme; (2) $N_2 = 5$ to 30 mole % of the gas volume is only present in the K2b black-schists which contain up to 7% organic carbon; and (3) away from the Dôme, N_2 was not detected in the fluid inclusions of the lower epizonal K2b formation which is free of hydrothermal alteration. Thus N_2 is present in fluid inclusions only in the black-schists affected both by an upper epizonal metamorphism and by an hydrothermal event. No evidence supports the hypothesis of a deep-seated source of N_2.

N_2 analyses were obtained by CHN analyser and infrared spectroscopy on both whole-rocks and micas (+ clay minerals). Several attempts in order to identify ammonium in biotite (at the level of ~0.2 wt %) by Raman microprobe analyses were performed without success. The K2b black-schists are by far the most N_2-rich formation. N_2 is present as ammonium in the micas (biotite) or clay minerals (illites), the carbonaceous material being N_2-free. The N_2 content of the K2b formation (whole-rocks and micas) is lower within the Dôme than away from this one. The lowest N_2 contents are observed in the host rocks of the stratiform scheelite mineralization (the L'Hom-Haut occurrence) where the metamorphic/hydrothermal alteration was intense (pyroxene- and biotite-bearing schists). In contrast, the fluid inclusions within the same rocks exhibit the highest N_2 content.

These results strongly suggest that N_2 in fluid inclusions was produced by the metamorphic/hydrothermal breakdown of NH_4^+-bearing micas. The primary origin of N_2 is the organic matter. Then it would be incorporated as NH_4^+ in the illitic fraction of the diagenetic clays. Finally NH_4^+-bearing micas would crystallize from illite during the epizonal metamorphic event.

Our study is now applied to the Dôme de l'Agout where a similar series, with abundant orthogneisses beside paragneisses and micaschists, was altered by high-grade metamorphism and anatexis. (Authors' abstract)

GUMIEL, J.C., QUILEZ, E., VINDEL, E. and BENY, C., 1989, Fluid inclusion study of San Nicolas W-Sn-Bi-Mo greisen deposit, Extremadura, western Spain (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 42. First author at Inst. Geol., Div. Investig. Mineras., Rios Rosas 23, 28003 Madrid, Spain.

The present study was initiated in order to investigate the physicochemical conditions of the ore solutions which prevailed during the formation of the San Nicolas W-Sn-Bi-Mo greisen deposit. This deposit is located in the boundary between the Central-Iberian and Ossa Morena Zone. The mineralization occurs as a swarm of subparallel quartz veins with ore shoots located in dilatant zones in the veins. These veins strike N35°-40°E, and are hosted by shales, quartzites and limestones of Lower Devonian age. The ore mineralogy comprises wolframite, cassiterite, molybdenite, stannite, bismuth, bismuthinite, arsenopyrite, pyrite, sphalerite, pyrrothite, chalcopyrite, quartz and fluorite. The ore deposit is probably related to a small highly evolved granitic cupola, which shows intense greisenization, albitization and potassic alteration.

FI have been studied in hydrothermal quartz, fluorite and greisen quartz veinlets using microthermometry, Raman-microprobe analysis and crushing tests. The FI are highly variable in density and composition. The fluids phases are characterized by fluids evolving from high-T (Th = 170-380°C) complex aqueous-carbonic solutions (CO_2-CH_4-N_2-NaCl-H_2O) to low-T (Th = 120-240°C) aqueous solutions (NaCl-H_2O). Their evolution corresponds to the mixing of early carbonaceous fluids with aqueous solutions. Ore deposition would occur during this process of mixing, with the early CO_2-CH_4-N_2-NaCl-H_2O fluid appearing to play an important role in W transport. (Authors' abstract)

GUNTHER, M.A. and **POHL, W.,** 1989, Primary gold mineralization in SW Rwanda: IGCP no. 255 meeting, "Recent Progress of Research on Kibaran (mid-Proterozoic) Evolution and Metallogeny," at Technical Univ., Braunschweig, F.R.G.

Investigations of FI in Sn, W, and Au deposits in the Kibara Belt of Rwanda, Burundi, and Uganda revealed the following characteristics of the original ore-forming fluids.

Early Sn and W fluids are CO_2-rich with moderate salinities (W: 6-8 wt % NaCl eq., K-Na pronounced; Sn: 8-10 wt % NaCl eq., K pronounced). At ~1 to 1.5 kb and 350 to 400°C, boiling occurred simultaneously with precipitation of most of the mineralization. The gaseous phase of the I has high N_2/CH_4-ratios and $N_2 + CH_4$ amounts of 6 to 20 mol %. Subsequently, precipitation of graphite occurred at ~250 to 300°C. Later fluids developed to lower T and lower P with a rise in salinity and Ca/Na-ratios. Latest fluids have very low salinities and $T < 100°C$.

In contrast to Sn and W, the hydrothermal systems producing Au-deposits started with CO_2-rich fluids with elevated salinities. Boiling occurred at ~450°C and 1.5 to 2.5 kb, and resulted in unmixing to highly saline fluids with very low CO_2-amounts (Na-Ca-K-Fe-Mn pronounced) and very CO_2-rich fluids with low salinities. The gaseous phase of the I contains very little CH_4 and/or N_2. Later fluids developed to lower salinities, lower CO_2-contents, lower T and lower P to non-saline fluids without CO_2 and $T < 100°C$.

Clearly, Sn and W fluids are G4-granite derived. The high amounts of CO_2, N_2 and CH_4 may have been extracted from organic matter of the host rock of the granite intrusions. Consequently, a front of gas-bearing fluids invaded the roof of the granites. Changing ratios of CO_2-CH_4 reveal a development path of the fluids especially concerning O fugacities: the fluids started at low O fugacities and developed to even lower fugacities resulting in precipitation of graphite at later stages of fluid development. The rise in salinities and Ca-Na ratios can be described as a reaction of the fluid with the granitic source rocks.

Early Au fluids had low O fugacities (although somewhat higher than in Sn and W fluids) and developed to higher ones. From mineral assemblages, fluid composition and PT-conditions a precipitation mechanism for Au can be modelled: In early fluids Au was transported in chloridic solution; P decline caused boiling of the fluids and precipitation of Au-bearing minerals as a result of Au solubility decrease. Later low T fluids (<300°C) possibly caused a redistribution of already precipitated Au, so that pyrite was replaced by hematite and native Au was reprecipitated.

Possible sources for Au-fluids are granitic intrusions or metamorphic/thermic events. An origin of the fluids from basic intrusions in the vicinity of the Au-deposits is improbable because of geologic reasons. However, barren fluids ascending from deeper regions could have dissolved Au (and Fe) from the basic rocks. Summarizing, a direct connection of the Au-deposits to the G4-granites seems improbable. (Abstract by W. Pohl, as published in Newsletter, Int'l Liaison Group on Gold Mineralization, no. 10, p. 24, 1989.)

GUO, Chunping, 1989, Experimental study on determination of gas composition of mineral inclusions by gas chromatography series connection system: J. Changchun Univ. Earth Sci., v. 19, no. 1, p. 99-104 (in Chinese; English abstract).

The paper reports a new method to separate and determine traces of H_2, O_2, N_2, CH_4, C_2H_8, CO, CO_2, and H_2O in mineral inclusions by gas chromatography series connection system. The sensitivity of this method for H in mineral inclusions is 7 g[sic]. The variation coefficient of gas chromatography series connection system for determining eight components in mineral inclusions is about 1~4%. (Author's abstract)

GUO, J.-G., CHEN, Feng, DENG, H.-X., TAN, Y.-M. and **DENG, E.-S.,** 1989, Preliminary investigation of mineral inclusions of diamonds from Hunan: Chinese Sci. Bull., v. 34, no. 7, p. 597-601 (in English).

GURENKO, A.A., POLYAKOV, A.I. and **KONONKOVA, N.N.,** 1987, Immiscible sulfide segregations in minerals of early crystallization stages of basaltic rock series: Dokl. Akad. Nauk SSSR, v. 293, no. 2, p. 171-174 (in Russian). First author at Vernadsky Inst. of Geochem., 117975, Moscow, Kosigin str. 19., U.S.S.R.

Globular sulfide segregations found in augite megacrysts from Pliocene olivine melanephelinite (south-central Transbaikalia, Burkal River) and immiscible sulfide in melt inclusions in magnesium olivine and clinopyroxene from Holocene tholeiitic basalt (Iceland rift zone, Teistareykir volcanic field) have been studied. All sulfide specimens from augite megacryst are structurally heterogeneous and consist of a Ni pyrrhotite core and a thin chalcopyrite rim.

The presence of [a constant volume % of] sulfide globules in melt inclusions trapped by magnesium olivine (92.2-88.5 mol % Fo) and clinopyroxene phenocrysts indicate that the melt separated into sulfide and silicate fractions after trapping. These argue that the melt was saturated in sulfur at an early stage of crystallization. As the system "melt inclusion-sulfide-crystal" is closed relative to S and Ni, based on microprobe analysis of coexisting sulfides and glasses, the S and Ni concentrations in parent melt have been calculated. They are (in ppm): S—960-1160; Ni—300-590. (Abstract by T. Sushchevskaya)

GURENKO, A.A., SOBOLEV, A.V. and KONONKOVA, N.N., 1989, New data on the petrology of ugandites from East-African Rift based on the results of investigations of the magmatic inclusions in minerals: Dokl. Akad. Nauk SSSR, v. 305, no. 6, p. 1458-1463 (in Russian). First author at Vernadsky Inst. of Geochem., 117975 Moscow, Kosigin str. 19, U.S.S.R.

Using the methods of mineralogy, geothermometry and magmatic inclusion investigation in minerals, the following major results on the petrology of ugandites (volcano Kazimiro, West Uganda) from the East-African Rift have been obtained: (1) Early olivine and spinel have Fo ≤91.0-86.0 mol % and Cr = 0.73-0.90, respectively, and low crystallization T (1150-1200°C); (2) Mg orthopyroxene is an early liquidus phase (occurs as inclusions in olivine phenocrysts); (3) fluid (determined by Raman spectroscopy) associated with melt is essentially CO_2; (4) melts, determined on a later crystallization stage and associated with second generation of olivine have extremely high alkalies, especially K, high Ti, P, Ba, Sr, F, and low Al and Ca. Thus the authors conclude that ugandite magma probably originated as a result of low-T melting of pre-depleted metasomatized lherzolitic (harzburgitic) mantle. Metasomatism was by a fluid (melt) with high CO_2/H_2O ratio. (Abstract by T. Sushchevskaya)

The studied specimen of ugandite (leucite picrite) has been collected from a lava flow of the Casimiro crater (W. Uganda) in 1967-1969. It bears two generations of phenocrysts: larger (0.5-3.0 mm) olivine crystals (Ol 1) and finer crystals of olivine (Ol 2), clinopyroxene, leucite and titanomagnetite (0.1-0.3 mm). The matrix consists of clinopyroxene (<100 μm), leucite, titanomagnetite, nepheline and phlogopite, and devitrified glass. The early olivine bears 91-86 mol % fo, the late olivine 88-81 mole % fo. Olivine phenocrysts bear the following P inclusions: partly and completely crystallized melt inclusions, crystal inclusions of clinopyroxene, orthopyroxene, chromian spinel, titanomagnetite, sometimes with fluid and globules of sulfide. Isolated fluid inclusions are rare—they are filled by LCO_2 (triple point -57.0 ± 0.3°C, density 0.76-0.69 g per cm^3; by Raman spectroscopy the filling contains probably also $CO < 1.8$, $N_2 < 1.0$, $H_2S < 0.2$, $CH_4 < 0.2$, $H_2O \leq 1.0$ mol %). From the LCO_2 inclusions, the P of the beginning of the Ol 1 crystallization was 3-4 kbar; Th of melt inclusions in Ol 1 and Ol 2 are 1000-1065°C. Dms in melt inclusions in leucite melt at 1100-1140°C, but homogenization has not been obtained, probably due to inclusion leakage. Homogenized melt inclusions in Ol 1 and Ol 2, by electron microprobe, gave the following melt compositions: SiO_2 41.83-43.25, TiO_2 4.67-5.66, Al_2O_3 10.33-10.62, [total Fe as] FeO 7.07-8.60, MnO 0.11-0.13, MgO 5.91-6.48, CaO 5.78-6.41, Na_2O 8.27-8.78, K_2O 9.30-9.70, P_2O_5 1.68-1.79, SrO 0.47-0.67, BaO 0.82-1.02, ZnO 0.03-0.11, Cr_2O_3 0.05-0.07. (Abstract by A.K.)

GURENKO, A.A., SOBOLEV, A.V., POLYAKOV, A.I. and KONONKOVA, N.N., 1988, Primary melt of Iceland rift tholeiites: The composition and conditions of crystallization. Dokl. Akad. Nauk SSSR, v. 301, no. 1, p. 179-184 (in Russian). First author at Vernadsky Inst. of Geochem., 117975, Moscow, Kosigin str. 19., U.S.S.R.

Using the methods of magmatic inclusion investigation in minerals and mathematical modeling, the composition and crystallization conditions of the primary melt of Iceland rift tholeiites has been obtained. This melt corresponds to picrite-basalt with 14 wt % MgO, being in equilibrium with olivine 92.2 mol % Fo. Primary melt, being undersaturated by fluid [sic], fractionated at 1300-1200°C and 8-10 kbar under oxygen fugacity conditions corresponding to FMQ buffer. The composition and conditions of crystallization of primary Iceland tholeiite melt are close to those for primary MORB melt (Dmitriev et al., 1985) but differ only in higher CaO and lower Al_2O_3. Following the experimental study of Takahashi and Kushiro (1983), the primary melt was determined to have been in equilibrium with a lherzolitic mantle source at 15-20 kbar. (Abstract by T. Sushchevskaya)

GUTHRIE, G.D., NAVON, O. and VEBLEN, D.R., 1989, Analytical and transmission electron microscopy of turbid-coated diamonds (abst.): Eos, v. 70, p. 510. First author at Dept. Earth and Planet. Sci., The Johns Hopkins Univ., Baltimore, MD 21218.

Analytical and transmission electron microscopy (AEM/TEM) and electron diffraction (ED) have been used to identify the solid phases in submicron inclusions in the turbid coats of diamonds from Zaire and several other localities. The presence of high concentrations of SiO_2, K_2O, water and carbonate in these inclusions previously was revealed by ion-probe microanalysis and IR spectroscopy (Navon et al, Nature, 335, 784-789, 1988); these results suggest that the trapped material represents a melt or a fluid from which the diamonds grew.

Observation of thin foils, prepared by argon-ion thinning of turbid diamond chips, revealed the presence of polymineralic assemblages of solid crystalline inclusions (generally ≤ 0.1 µm) contained within negative-crystal cavities (generally ≤ 0.2 µm) in the diamond. At least four solid phases have been distinguished. Apatite inclusions were identified with AEM and ED. Carbonate inclusions were identified with AEM and the IR data. Silicate inclusions rich in K, Al, and Fe with smaller amounts of Mg, Ti, S, and Cl were identified based on AEM, ED, and the IR data; ED data indicated the presence of a 1.0-nm sheet silicate, but some of the AEM data were inconsistent with any known sheet silicate. Si-rich inclusions (probably SiO_2) were identified with AEM.

TEM showed that the solid inclusions generally possess euhedral morphologies, suggesting that they may have grown from a melt or fluid originally trapped in the diamond. In some cases, the solid inclusions appeared to fill a significant portion of the cavities when viewed in projection, suggesting that the trapped material contained a relatively small proportion of volatile components. No direct observation of fluid has been made. This may be a result of the rapid loss of volatiles from open cavities in the high vacuum in the TEM.

The mineralogy of the phases as well as the bulk composition (inferred from the ion-probe data) is distinct from the mineralogy of the larger, predominantly monomineralic, peridotitic and eclogitic suite diamond inclusions. This strongly implies a different environment of formation for the turbid coats and limpid interiors. (Authors' abstract)

GUTHRIE, G.D., Jr. and VEBLEN, D.R., 1989, Transmission electron microscopy of fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A286. Authors at Dept. Earth and Planetary Sciences, The Johns Hopkins Univ., Baltimore, MD 21218.

Despite its unique ability to provide spatial, structural, and compositional information on a fine scale, transmission electron microscopy (TEM) has been used to study fluid inclusions only rarely. A few studies (e.g., McLaren and Phakey, 1966, Aust. J. Phys., 19, 19-24, Green and Gueguen, 1983, Tectonophysics, 92, 71-92; Lang and Walmsley, 1983, Phys. Chem. Min., 9, 6-8; Guthrie and Veblen, 1987, Eos, 69, 267; Guthrie et al., 1989, Eos, 70, 510) have demonstrated that TEM can be used to characterize many aspects of fluid inclusions which cannot be addressed by conventional techniques. Daughter products can be identified and their compositions determined using electron diffraction and energy-dispersive X-ray spectrometry. In addition, many fluid inclusions are smaller than 1-2 µm, which is below the resolution of microthermometric analysis with the light microscope. Inclusions of this size, however, at not below the resolution of the TEM, which is capable of resolving structural and spatial detail in the subnanometer range and compositional detail to about 10 nm. Specially equipped sample holders are capable of heating or cooling a specimen over the same range of T needed for microthermometric analysis. Thus, in some cases, it may eventually be possible to freeze or homogenize fluids during observation in the TEM, with electron diffraction providing structural data about the frozen liquid.

The main limitation of this technique is that the samples must be extremely thin (<100 nm for most microscopes) in order to allow penetration of electrons. Electron transparent samples commonly are prepared by grinding, slicing, or ion thinning, each of which may open fluid inclusions. When the fluid inclusions are small, inclusions located fortuitously can be examined intact. Larger inclusions are nearly always opened during the sample preparation process. However, in many cases, dxls remain attached to the cavity wall and can be identified. Often crystals (e.g., NaCl) will precipitate on the specimen surface as the fluid exits the ruptured cavity, leaving clues to the fluid composition.

Though TEM will not replace standard techniques for studying fluid inclusions, it can provide important additional information, especially when the inclusions are too small to be studied by light microscopy. (Authors' abstract)

GÜENTHER, M.A., 1989, The VX-projection of the pseudobinary systems H_2O-CO_2-(6 wt %)-NaCl and H_2O-CH_4-(0.6, 1.7 and 8 wt %)-NaCl: A practical method avoiding degree of fill estimation of fluid inclusions (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 52. Author at Technical Univ., D-3300 Braunschweig, F.R.G.

Fluid inclusion research work bears one important source of error: the visual estimation of degree of fill (see Roedder, 1984, p. 280 on). The error of estimation in inclusions with a degree of fill between 50% and 100% aqueous phase can be rated as 5% or 10% depending on the form and size of the particular fluid inclusion. The error for a degree of fill below 50% can sometimes increase up to 100%. Estimating the degree of fill is at present the most important method used for calculations of inclusion composition and density.

Therefore, J. Walther has introduced a special method to avoid this estimation (Ph.D. thesis, 1981) by using VX-projections (see Lentz, 1979) of experimental data for fluid systems. The precision of composition and density estimations increases with a factor of ten or even more. Additionally, inclusions with very low degree of fill can be determined by this method. On the other hand, this method reveals the possibility of determining boiling effects or P estimations at Th of the particular inclusion. Such estimations had not been possible with comparable precision.

Walther (1981) determined his diagrams only for H_2O-CO_2 by using literature data (Tödheide and Franck, 1963; Frank and Tödheide, 1959; Malinin, 1959; Gehrig, partly unpublished). But more complex fluids occur in natural fluid inclusions. Such fluids can be estimated by gas-water-electrolyte mixtures. The most simple configuration of such a system is H_2O-CO_2-NaCl. This system was determined in a sufficient way only in the pseudobinary region of 6% NaCl (Gehrig et al., 1986). The author used these data for the construction of this pseudobinary system with the method after Walther and Lentz (Walther and Guenther, in preparation). After rework of some literature it was possible to calculate the carbon dioxide solubility in an aqueous salt solution up to 25 wt % NaCl between 0° and 50°C and CO_2 pressure. With data from Krader et al. (1986), the same processing was applied to the system H_2O-CH_4-NaCl.

For determination of density, composition and minimum P of suitable fluid inclusions, only the Th CO_2, the Ttot and the salinity (which should lie around 6 wt % NaCl) are required. (Author's abstract)

GÜENTHER, M.A. and POHL, W., 1989, Fluid inclusions in gold deposits of Rwanda and Burundi, central Africa (abst.): Terra Abstracts, v. 1, p. 33-34. Authors at Tech. Univ., Inst. Geol., P.O. Box 3329, D-3300 Braunschweig, FRG.

Au quartz veins occur in SW-Rwanda and NW-Burundi (district Nyungwe-Mabayi), N-Rwanda (district Miyove), and NE-Burundi (district Muyinga). The veins show different paragenesis: iron oxide-rich veins with little quartz (type Ntendezi-Ruhororo, district Nyungwe-Mabayi), pyrite- and arsenopyrite-rich quartz veins (type Cyurugeyo-Gasarabwe, district Nyungwe-Mabayi), and jasper- and pyrite-bearing quartz veins (districts Miyove and Muyinga). Recent studies of FI in vein quartz have revealed a nearly identical fluid evolution in both oxide and sulfide vein types of the district Nyungwe-Mabayi. There, the initial stages are represented by two types of FI: AI with predominantly (40-90 wt %) liquid CO_2, about 8% NaCl eq. and Th of 300-380°C (estimated only as decrepitation on heating is the rule), and AII with mainly aqueous liquid, liquid CO_2 and large halite, calcite, and tourmaline dxls, 30-40% NaCl eq., and a Th of 100-400°C. Formation P are estimated as 2-3 kb. Later AIII inclusions are aqueous with usually small calcite dxls and trend to lower Th (220-260°C) and lower salinities (7% NaCl eq.). Comparative data on the districts Miyove and Muyinga will be presented. FI data of some granite related Sn and W deposits show, that the Au deposits must be seen apart from these deposits. The source of the Au mineralization is not yet known. (From authors' abstract by E.R.)

HAGEMANN, St.G. and WALDE, D.H.G., 1989, A preliminary fluid inclusion study of the shear zone related low grade gold deposit near Luziania (Brasilia fold belt), Goias, Brazil (abst.): Terra Abstracts, v. 1, p. 34. Authors at Dept. Geosciences, Univ. Wisconsin,

Aqueous and carbonic FI in mineralized quartz veins and boudins have been examined by microthermometry. Two stages of fluid circulation were reconstructed for the history of the aqueous and carbonic fluids: Stage 1 has two types, Type 1: P, pure CO_2 and CO_2-bearing aqueous FI of high density (d CO_2 = 0.94 gcm^{-3}), low salinity (6.45 wt % NaCl) suggesting an early release of fluids at ~360-480°C. Type 2: CO_2-bearing aqueous FI (88.97 mole % H_2O, 1.60 mole % NaCl, 8.41 mole % CO_2, 1.00 mole % CH_4; d = 0.95 gcm^{-3}) with significantly lower Th (200-360°C) suggesting a continuing release of CO_2 due to different P + T conditions during the thrusting event.

Inclusions related to the second stage are either pure aqueous inclusions with moderate salinity (7.14-14.09 eq. wt % NaCl) or CO_2-bearing aqueous fluids with only traces of CO_2 (2-3 mole %) and CH_4, Th = 200-300°C.

The fluids related to the first stage are interpreted to have been released during a Late Proterozoic piggy back thrust event. The fluids were expelled from the underplate and penetrated along the thrust plate to upper levels.

The second stage in the fluid circulation, late in the tectonic evolution and at shallower crustal levels could be explained by a gradual dilution of cooler, moderately saline, oxidizing, near-surface fluids reservoirs into the fault zones.

This two-stage fluid circulation model could explain the transport and precipitation of Au in the quartz veins and boudins in the Luziania Au deposit. (From authors' abstract by E.R.)

HAGGERTY, J.A., 1989, Fluid inclusion studies of chimneys associated with serpentinite seamounts in the Mariana Forearc (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 29. Author at Dept. Geosci., Univ. Tulsa, Tulsa, OK 74104.

The Mariana Forearc region has serpentinite seamounts, located 50 to 120 km from the trench axis, with chimneys on their summits seeping cold water. The chimneys are composed of aragonite, calcite, and a nearly amorphous Mg-silicate mineraloid. The carbon and oxygen isotopic signature of the carbonate minerals suggests a mixing line with two sources of fluids from which the minerals precipitated. One fluid appears to be related to a CH_4 source and the other is seawater. FI studies of the volatile components have verified the presence of CH_4 in the fluids associated with the precipitation of the authigenic minerals. Also detected are aromatic compounds, long-chain paraffins, naphthenes, and acetate ions. The presence of aromatic compounds (benzene, toluene, and xylene) and other organic compounds indicate a thermogenic origin; the presence of the acetate ions limits the T range of the source region of the organics to <150°C.

The Mariana subduction system is classified as a non-accretionary system and tectonic erosion has been suggested to occur in the forearc. Fryer et al. (1985) suggested that these seamounts formed by diapiric emplacement of the serpentinite. Fluids driven off the downgoing slab by compaction, desiccation, and dehydration, hydrate the over-riding plate and form the serpentinite. Fluids expelled from the chimneys atop these seamounts may be partially derived from the downgoing plate. In addition to dehydration, the FI and isotopic data suggest that some of the venting fluids are derived from thermal maturation of organic matter in the downgoing plate. (Author's abstract)

HAGGERTY, J.A. and **CHAUDHURI, S.**, 1989, Strontium isotopic analyses of aragonite from cold-water chimneys atop Mariana forearc seamounts: Implications for fluids from the subducting slab (abst.): Eos, v. 70, p. 1380.

HAGGERTY, J.A. and **SMITH, M.P.**, 1988, Characterization of diagenetic fluids of the Upper Jurassic-Lower Cretaceous carbonate platform of the Galicia margin at Ocean Drilling Program Site 639: Evidence for dolomitization by hypersaline brines, *in* G. Boillot, E.L. Winterer et al. (eds.), Proc. Ocean Drilling Program, Scientific Results, v. 103, p. 145-153. First author at Dept. Geosciences, Univ. Tulsa, Tulsa, OK.

Site 639, drilled during Leg 103 of the Ocean Drilling Program, penetrated an Upper Jurassic to Lower Cretaceous carbonate platform on a tilted fault block along the Galicia margin off the northwest Iberian Peninsula. The carbonate platform is composed primarily of a sequence of dolomite overlying limestone. Samples were analyzed for mineral chemistry, stable isotope geochemistry, fluid inclusion microthermometry, and volatile contents and dolomite pyrolysis mass spectrometry for trace sulfate minerals. The dolomite recovered from the Galicia margin at Site 639 formed during shallow burial from sulfate-bearing, hypersaline brines at slightly elevated T. The light O isotopic signatures of the dolomite are interpreted as the result of the evaporative loop and slightly elevated T during dolomite formation or from reequilibration at higher T during deeper burial. The hypersalinity is interpreted to be associated with a nearby, shallow restricted basin that formed during rifting of the Iberian margin from Newfoundland. The dolomitization of the platform is therefore a by-product of the rifting. (Authors' abstract)

HAGGERTY, S.E., 1989, Upper mantle oxidation state and diamond genesis (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 26-28.

HAGNI, R.D., 1989, The Southeast Missouri lead district; a review, *in* R.D. Hagni and R.M. Coveney, Jr., eds., Mississippi Valley-type Mineralization of the Viburnum Trend, Missouri: Univ. Missouri at Rolla, Dept. Geology and Geophysics, Rolla, MO, Guidebook Series, v. 5, p. 12-57.

Only literature data given. (H.E.B.)

HALBACH, P., WAHSNER, M., KÄSELITZ, L., SAKAI, H. and **HEIN, U.**, 1989, The Jade hydrothermal field in the Okinawa Trough—First discovery of massive sulphides in an intracontinental back-arc basin: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 279-283. First author at Technical Univ. of Clausthal, FR Germany.

The Okinawa Trough is a tectonically active back-arc basin where magma supply systems and extension processes create hydrothermal circulation. The Jade hydrothermal field was detected in a caldera-like structure in the middle Okinawa Trough. Four different varieties of seabed sulphide mineralizations were identified. Some of the mineral samples are very rich in Ag and Au. First research results allow the conclusion that this deposit is a recent analogue of the Kuroko type massive sulphides. (Authors' abstract)

Th of 133-196°C (plus P correction of 15°C) and Tm ice of -2.1 to -3.9°C. (E.R.)

HALL, A.J., BANKS, D., FALLICK, A.E. and **HAMILTON, P.J.**, 1989, An hydrothermal origin for copper-impregnated prehnite and analcime from Boylestone Quarry, Barrhead, Scotland: J. Geol. Soc., London, v. 146, p. 701-713. First author at Dept. Applied Geology, Univ. Strathclyde, Glasgow G1 1XJ, U.K.

Field, petrographic, mineralogical, fluid inclusion and stable isotope studies of prehnite, analcime and calcite in basalt lava of Visean age (about 360 Ma) from Boylestone Quarry, Barrhead, Scotland, are all consistent with an hydrothermal origin. In the hydrothermal system, water interacted with hot alkaline basalt soon after eruption. Feldspars were digested in an alkaline solution, and alumina and silicate were reprecipitated in fractures and veins as the hydrous alumino-silicates analcime and prehnite. The prehnite generally occurs below the analcime in more oxidized host basalt. Minor calcite crystallized late, usually on earlier analcime or prehnite. Fluid inclusion measurements give Th of 83-184°C (mean 145°C) and salinities *c.* 1.5 eq. wt % NaCl for analcime; and *c.* 46-234°C and *c* 26 eq. wt % NaCl for calcite. Fluid inclusions in analcime appear to contain some SO_4^{2-} or CO_3^{2-}. Inclusions in calcite associated with prehnite have a lower Ca^{2+}:Na^+ ratio that those in calcite associated with analcime. Using a fluid inclusion T of 145°C for analcime of $\delta^{18}O$ = 15.6‰ (V-SMOW) implies $\delta^{18}O$ for the fluid was 1.4‰ and this leads to 184°C for the T of precipitation of prehnite of $\delta^{18}O$ = 12.5‰. The δD values of -35‰ for prehnite are consistent with surface water (seawater or low latitude meteoric water) heated to 180°C. Two groups of calcite are recognised on fluid inclusion and isotopic evidence: Both groups have δD values ranging from -61 to -117‰, but one group is characterized by Th > 100°C and $\delta^{18}O$ = 20 to 22‰ ($\delta^{18}O_{water} \approx$ 10.3‰) and is believed to have formed from surface waters which had exchange ^{18}O with igneous rocks at a high T, whereas the second group with Th ≈ 85°C and $\delta^{18}O \approx$ 17.2‰ crystallized from normal surface waters of $\delta^{18}O_{water}$ = -0.4‰. The carbonate $\delta^{13}C$ data (range -8.3 to -42.4‰ PDB) attest to the presence of organic-derived carbon dioxide in the hydrothermal fluid, as expected since organic material is observed in some fluid inclusions. The low $\delta^{13}C$ value, -42.4‰, indicates oxidation of methane, whereas the higher values point to decarboxylation of organic matter.

Cu was oxidized and remobilized from disseminated chalcopyrite in basalt and probably from disseminated Cu minerals which had resulted from Carboniferous weathering of underlying basalts. Dissolved Cu was reprecipitated on cooling and reduction, generally within and above greenish prehnite.

The fluid inclusion and isotope studies indicate that the water could well have been mainly meteoric with, in addition, some warm Lower Carboniferous seawater and/or saline groundwaters; the water interacted with organic-rich sediments to provide CH_4 and CO_2 then the various degrees with hot igneous rock. The hydrocarbons may have been mobilized into groundwaters by baking of organic sediments in the Cementstone Group. The model is consistent with active volcanogenic geothermal activity during Lower Carboniferous times in the Midland Valley of Scotland. (Authors' abstract)

HALL, D.L., Jr., 1985, Contact metamorphism, hydrothermal alteration, and iron-ore deposition in the south-central Marble Mountains, San Bernardino County, California: MS thesis, Univ. California, Riverside, CA.

See Hall and Cohen, 1986, Fluid Inclusion Research, v. 19, p. 171-172. (E.R.)

HALL, D.L., 1989, Fluid evolution during metamorphism and uplift of the massive sulfide deposits at Ducktown, Tennessee, U.S.A.: PhD dissertation, Virginia Polytech. Inst. and State Univ., Blacksburg, VA.

The Ducktown mining district, located in the southeastern corner of Tennessee within the Blue Ridge Province of the southern Appalachians, contains some of the largest metamorphosed pyrrhotite-pyrite-rich massive sulfide deposits in the Appalachian-Caledonian orogen. O isotope T of 530 ± 20°C are consistent with previous estimates based on mineral thermobarometers (540 ± 40°C; 6-7 kb) suggesting that minerals attained O isotopic equilibrium during peak metamorphism and underwent little retrograde exchange. FI and petrologic data do not support the previous interpretation that low $\delta^{18}O$ zones near orebodies are synmetamorphic, rather, a premetamorphic origin is indicated. Integrated fluid/rock ratios were low enough during and after metamorphism that premetamorphic spatial variations in $\delta^{18}O$ were retained. However, H and C isotopes were homogenized throughout the area during or before metamorphism. The $\delta^{18}O$ zones surrounding the orebodies appear to have formed during sea-floor hydrothermal activity associated with ore deposition. The $\delta^{18}O$ value of the fluid responsible for ore deposition, assuming a T of 300°C, is calculated to be -1 to +2‰, consistent with the interpretation that the ore fluid was modified seawater.

Calculation of theoretical C-O-H-S fluid speciation suggests that the fluid in equilibrium with clinopyroxene-bearing rocks was essentially $H_2O + CO_2$ with $XCO_2 = 0.10$. However, P FI located in clinopyroxene contain significant quantities of CH_4. This discrepancy is explained by H diffusion *into* P FI and subsequent conversion of CO_2 to CH_4 during uplift in response to an fH_2 gradient between I and matrix fluids. Low δD values of P FI are consistent with diffusive addition of isotopically light H after trapping.

S I in metamorphic quartz record a complex uplift history involving a variety of fluids in the C-O-H-N-NaCl system. Isochores calculated for these I constrain the uplift path to have been initially concave toward the T axis. Over the P range 2.3 to 1.0 kb the uplift path became nearly isothermal at 215 ± 20°C. Immiscible H_2O-CH_4-N_2-NaCl fluids present during the isothermal stage of the uplift history were derived during Alleghanian thrusting by expulsion of pore fluids and maturation of organic matter in lower plate sedimentary rocks proposed to underlie the deposits. Average uplift rates of 0.1 mm/yr are suggested by the uplift path and available geochronologic data. (Author's abstract)

HALL, D.L. and **BODNAR, R.J.**, 1989a, Methane in fluid inclusions from granulites: A product of hydrogen diffusion? (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 30. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

Many FI studies of granulite grade rocks reveal the presence of CO_2-rich inclusions which appear to have been trapped at the peak of metamorphism. Final melting T of CO_2 (Tm CO_2) reported for these inclusions are often below -56.6°C—some approach -60°C. Independent evidence from Raman or mass spectroscopy suggests that CH_4 is present in many of these inclusions. It is often claimed that Tm CO_2 near -56.6°C indicates "nearly pure CO_2" inclusions; however, even small depressions from this value suggest that significant amounts of CH_4 may be present. For instance, Tm CO_2 of -57.0°C implies 3 mole % CH_4 in the liquid phase of a pure CO_2-CH_4 inclusion. Furthermore, the vapor coexisting with this liquid contains about 50 mole % CH_4 so that the bulk composition of the inclusion may contain several mole % more CH_4 than indicated by Tm CO_2, depending on the volume % vapor and its density at Tm CO_2.

C-O-H ± S fluid speciation calculations for conditions representative of granulite facies metamorphism, as suggested by mineral assemblages (700-800°C, 5-8 kb, log fO_2 = FMQ ± 1, ± graphite), indicate that while CH_4 may comprise a significant portion of peak metamorphic fluids when graphite is present, it is never a significant species in CO_2-rich fluids and in most cases should be virtually undetectable with microthermometric or spectroscopic techniques. Only in aqueous FI can CO_2 and CH_4 both be significant species. Post-trapping speciation changes to FI at constant mass cannot account for reported compositions unless graphite precipitates in the inclusions; thus, explication of observed compositions appears to require post-trapping compositional changes due to loss or gain of components.

To investigate this possibility we have modeled variations in fugacities of molecular fluid species in inclusion and matrix fluids during a uplift from 6 kb and 800°C, assuming hypothetical isothermal and isobaric uplift paths. Our results suggest that for rocks buffered at fO_2 within one log unit of FMQ most uplift paths result in external fH_2 overpressures of bars to tens of bars at above 400°C. The highest overpressures are generated during isobaric uplift. Compositional changes resulting from equilibration of such gradients, via hydrogen diffusion *into* peak metamorphic FI and reduction of CO_2 to CH_4, are consistent with compositions of FI reported from granulite terranes. Although each case must be investigated separately, in general, our data suggest that CH_4 contents greater than 5-7 mole % can be achieved only during isobaric uplift. Thus, the CH_4 content of inclusions in granulites, coupled with P-T-fO_2 conditions of peak metamorphism, may be used to place constraints on uplift paths even in the absence of suitable S inclusions.

It has been postulated that CO_2-rich FI in granulites could originate from post-trapping diffusive loss of H_2O from H_2O-CO_2 inclusions in response to an fH_2O gradient between inclusion and matrix fluids. The results of the present study suggest that for fluids buffered by FMQ ± 1 this is possible only if (1) uplift is isothermal and the matrix fluid composition remains nearly constant, or (2) the matrix fluid evolves toward relatively H_2O-poor compositions. The latter could occur if graphite precipitates during uplift. (Authors' abstract)

HALL, D.L. and **BODNAR, R.J.**, 1989b, Comparison of fluid inclusion decrepitation and acoustic emission profiles of Westerly granite and Sioux quartzite: Tectonophysics, v. 168, p. 283-296.

Acoustic emissions recorded during slow heating of rocks at 1 atm have generally been attributed to intergranular stresses generated by differences in thermal expansion coefficients and elastic moduli of neighboring grains. These experiments have considered only the solid phases in analysis of the results, and little attention has been given to the role of intragranular or grain boundary fluid inclusions in initiating or facilitating fracturing.

In principle, fluid inclusions may be thought of as a special case in which the "neighboring grains" are fluids rather than the usual solid mineral phases. The major differences are that (1) the number of inclusions per unit volume is usually 10^2 to 10^6 times greater than the number of mineral grains in that same volume and that (2) the volume increase with T for most fluids is 1-2 orders of magnitude greater than for minerals. Thus, when fluid inclusion "grains" are considered, the absolute number of grain-to-grain contacts in a given sample volume is several orders of magnitude greater than if inclusions are not considered. Further, the magnitude of the stresses between any two adjacent grains may be much higher if one of the "grains" is a fluid inclusion, owing to the larger coefficient of thermal expansion of the fluid relative to a solid phase. As a result, substantial overpressures may be generated at the fluid inclusion "grain"-mineral grain contact, during heating experiments. These overpressures result in brittle failure when the stress around the inclusion exceeds the local strength of the host crystal. In fluid inclusion terminology, this fracturing event is referred to as decrepitation.

Samples of Westerly granite and Sioux quartzite were heated at 2°C/min in a gas-flow stage in order to determine the decrepitation profiles (number of decrepitations as a function of T) of these rocks. Decrepitation was monitored visually during heating experiments and was evidenced by the explosive loss of fluids from the inclusion during a fracturing event. Decrepitation produces microfractures which originate at decrepitated fluid inclusions and propagate outward into the surrounding mineral. Four different types of inclusions, based on room T phase ratios and distribution within the host phase, were noted in Westerly granite. Type (1) inclusions contain a single aqueous liquid, type (2) are two-phase, liquid-rich inclusions, type (3) are mostly one-phase fluid inclusions that occur in dense clusters in plagioclase, and type (4) are two-phase, moderate-density, H_2O-CO_2-"salt" inclusions. Type (5) inclusions are one-phase, aqueous liquid inclusions observed in Sioux quartzite.

Fluid inclusions in Westerly granite decrepitate between 75° and 573°C with peaks at 275-300°C and 400-450°C. Type (4) inclusions in Westerly granite tend to decrepitate at lower P (75-300°C) than other inclusion types. Initial fracturing of the quartz host surrounding type (1) inclusions (P decrepitation) generally occurs over the range 100-400°C and the fractures continue to propagate through the quartz (secondary decrepitation) during further heating from 400 to 573°C. Fluid inclusions in Sioux quartzite decrepitate between 188 and 573°C with a broad maximum at 250-450°C. P decrepitation generally occurs at 200-450°C while secondary decrepitation occurs at 350-573°C in Sioux quartzite. Some small inclusions in both samples do not decrepitate until the quartz α-β transition T (573°C) is reached. (Authors' abstract)

HALL, D.L., BODNAR, R.J. and **CRAIG, J.R.,** 1989a, Fluid inclusions from the metamorphosed massive sulfide deposits at Ducktown, Tennessee: Constraints on uplift and evidence for hydrogen diffusion (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-11. Authors at Virginia Polytech. Inst. & State Univ., Blacksburg, VA.

The Ducktown mining district is located in the southeast corner of Tennessee in the Blue Ridge Province of the Southern Appalachians. Eight ore bodies ranging in size from 250,000 to 70,000,000 tons and averaging 60% pyrrhotite, 30% pyrite, 4% chalcopyrite, 4% sphalerite and 2% magnetite are contained within late Precambrian metagraywacke, quartz-mica schist, quartzite, metaconglomerate and calc-silicate hornfels. The orebodies are envisaged to have been formed in a steep-walled submarine graben during intracratonic rifting associated with incipient formation of Iapetus.

The orebodies and their host rocks have undergone three episodes of metamorphism and at least five episodes of deformation. Prograde metamorphism produced a Barrovian-type sequence of metamorphic mineral assemblages with maximum grade of middle-amphibolite facies characterized by the assemblage staurolite ± kyanite. Previous workers have constrained P-T conditions of peak metamorphism to have been 6 ± 1 kb and 550 ± 40°C.

P fluid inclusions, observed in pyroxene from all major orebodies, contain a low salinity (3 wt %) H_2O-CH_4-NaCl fluid and dm calcite, quartz and pyrrhotite. Re-integrating solids, liquid and vapor into a homogeneous fluid phase and considering only the volatile constituents yields an estimated fluid composition of $X(H_2O) = 0.93$, $X(CH_4) = 0.04$, $X(CO_2) = 0.03$ and $X(H_2S) = 0.001$.

Fluids with a wide range of compositions in the system C-O-H-N-salt were present during the uplift history of the deposit and are now recorded as S inclusions in quartz. From oldest to youngest these are: (1) high-density, 0-6 wt % NaCl-H_2O; (2) high-density H_2O-CO_2-NaCl ($\pm CH_4 \pm N_2$) inclusions containing 10-15 mole % CO_2 and 3-6 wt % NaCl; (3) immiscible H_2O-CH_4-N_2-NaCl fluids indicating trapping at 215°C and 2.78 kb; (4) halite-bearing inclusions which cannot be frozen and have salinities of 33 wt % NaCl eq.; (5) late-stage, high-density $CaCl_2$-$MgCl_2$-NaCl-H_2O inclusions with final Tm ice of -9° to -43°C. Isochores for the above inclusion types, calculated from available data and from decrepitation behavior constrain the P-T time path to be counterclockwise and imply geothermal gradients which decrease from 24°C/km at peak metamorphism to 18°C/km, and then increase to 25°C/km in the waning stages of uplift, assuming $P_L = P_F$.

Theoretical C-O-H-S fluid speciation calculations suggest that $H_2O + CO_2$ generally comprised 94-100 mole % of the molecular species in the peak metamorphic fluid over the entire range of fO_2-fS_2 conditions indicated by silicate-sulfide-oxide ± graphite equilibria at Ducktown. Other significant species were CH_4 ($\leq$5 mole %) at low fO_2-fS_2 and H_2S ($\leq$3 mole %) at low fO_2-high fS_2. The fluid associated with rocks bearing P fluid inclusions is calculated to be essentially $H_2O + CO_2$ with $X(CO_2) = 0.10$ and $X(H_2S) = 0.001$. This composition is clearly in disagreement with the re-integrated H_2O-CH_4-CO_2 fluid actually present in these inclusions. Furthermore, calculations suggest that CH_4 is never a significant component at P-T-fO_2-fS_2 conditions indicated by mineral assemblages in pyroxene-bearing rocks; its presence suggest a much more reducing environment.

We believe that hydrogen diffusion *into* primary fluid inclusions has occurred during uplift in response to an fH_2 gradient between inclusion and matrix fluids. Modeling the post-trapping behavior of hypothetical peak metamorphic fluid inclusions and their host rocks over the range 550-400°C indicates that during the initial stages of uplift, a modest fH_2 gradient may have been established if the matrix fluid composition was buffered by the local mineral assemblage (Py-Po-Mt). However, if fluid infiltrated from the more reduced country rock (Po-Ilm-graph), fH_2 gradients would have been substantial (e.g., 45-35 bars at 550-400°C) and H diffusion into P fluid inclusions would have been likely. In this case, to equilibrate fH_2 inside and outside of peak metamorphic fluid inclusions at 450°C, an amount of H approximately equal to 12.5% of the total H originally present in the inclusions must diffuse in. This would have profound effects on the P-V-X properties of the trapped fluid. Most importantly, the final composition of the fluid inclusions would be $X(H_2O) = 0.90$, $X(CO_2) = 0.07$, $X(CH_4) = 0.03$ and $X(H_2S) = 0.001$, which compares favorably with the actual composition estimated from P fluid inclusions. (Authors' abstract)

HALL, D.L., BODNAR, R.J. and **CRAIG, J.R.,** 1989b, Fluid inclusion and stable isotope systematics of the metamorphosed massive sulphide deposits at Ducktown, Tennessee, USA (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 43. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061, USA.

The Ducktown deposit is one of many metamorphosed stratiform massive sulphide occurrences within the Appalachian-Caledonian orogen. Based on mineral equilibria, previous workers have constrained P-T conditions of peak metamorphism to have been 540 ± 40°C and 6 ± 1 kb. Isotopic T calculated from $\delta^{18}O$ values of concordant mineral triplets give final equilibrium T of 530 ± 20°C. P FI are ubiquitous in clinopyroxene ($Di_{80-94}Hd_{3-17}Jo_{3-6}$) from all major ore bodies. These contain H_2O-CH_4-NaCl fluids and dxls of quartz, calcite and pyrrhotite. S FI in quartz contain a variety of C-O-H-N-Na-K-Mg-Ca-Cl fluids and constrain the P-T-time path to have been counterclockwise with implied geothermal gradients of 18-25°C/km.

The CH_4/CO_2 ratios in P FI are inconsistent with calculated mole fractions of fluid species of fO_2 conditions indicated by mineral assemblages. These calculations suggest that P FI should contain H_2O-CO_2 fluids with 10 mole % CO_2 and no detectable CH_4. Post-trapping compositional changes cannot account for the discrepancy if the inclusions behaved as closed systems. We believe that H_2 diffusion into P FI has occurred during uplift in response to fH_2 gradients between inclusions and matrix fluids. This hypothesis is supported by a model of post-entrapment compositional variations in hypothetical P FI and later metamorphic fluids during uplift along the P-T-time path delineated by S FI in quartz. The model reveals that substantial fH_2 gradients may have been established if fluids buffered by graphitic country rocks infiltrated the relatively oxidized ore zones during uplift. These fH_2 gradients would promote fH_2 diffusion in P FI and reduction of CO_2 to $CH_4 + H_2O$.

Previous workers have noted that minerals in chlorite-rich and muscovite-rich lithologies near the ore bodies are depleted in $\delta^{18}O$ by an average of 2‰ compared to their counterparts in the country rocks, resulting in whole-rock depletions of up to 6‰. After integrating data from FI and stable isotopes, we believe that low $\delta^{18}O$ zones near the ore bodies are syngenetic and resulted from interaction of hot, hydrothermal solutions with the host turbidites during ore deposition. Subsequent regional metamorphism did not appreciably affect large scale $\delta^{18}O$ distributions, although grain-scale equilibration did occur. These observations suggest that peak metamorphism occurred at relatively low fluid/rock ratios. (Authors' abstract)

HALL, D.L., STERNER, S.M. and BODNAR, R.J., 1989a, Fluid inclusions in regional metamorphic rocks: Experimental evidence for post-entrapment volumetric and compositional modifications (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 44. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061, USA.

Field evidence for post-entrapment volumetric changes in FI from metamorphic rocks is common. Compositional changes, although suspected from mineral equilibria calculations, are rarely unequivocal. In order to quantify these phenomena we have monitored the volumetric and compositional changes in synthetic FI in Brazilian quartz when subjected to differential P (ΔP = internal P - external P) at elevated T.

Pure H_2O inclusions reequilibrated at 700°C and ΔP of +4 kb to -5 kb for 7 days displayed intermediate densities indicating partial reequilibration to within 0.75 to 2 kb of the new confining P. Similar experiments conducted for 52 days produced inclusions which had equilibrated to within 0.1 kb of the new confining P. Inclusions subjected to internal overpressures generally tended toward negative crystals while those subjected to internal underpressures became surrounded by a halo of smaller inclusions--a texture often attributed to decrepitation due to internal overpressure. The above observations suggest that 10-30 µm FI in quartz will not withstand ΔP of +1.5 kb or -2 kb for geologic time. Consequently, isochores calculated for FI from regional metamorphic terrains may represent neither a minimum nor a maximum P-T trajectory.

To evaluate the importance of H_2O diffusion, inclusions containing 10 and 42 wt % NaCl solutions trapped at 3 kb and 600°C were reequilibrated at 600°C and 1 kb for 5 days in dry argon. Salinity determinations indicate that original compositions were preserved to within the limits of measurement (±0.15 wt % NaCl); thus, all density changes in these samples can be attributed to increases in inclusion volumes without loss of contents by diffusion or leakage. Similar experiments were conducted on inclusions trapped from 57 wt % NaCl solutions at 1.5 kb and 600°C or 3 kb and 825°C. These were reequilibrated at 1.5 kb and 825°C for 0.5 to 35 days. The inclusions displayed substantial density changes and tended toward negative crystals. In addition, salinities increased to a maximum of 80 wt %. A strong negative correlation between salinity and inclusion volume was seen in all samples and salinities increased progressively with time. These observations are consistent with diffusional loss of water from the inclusion into the quartz host. We calculate a flux of 2.2×10^{-11} $gmcm^{-2}sec^{-1}$ for this process. (Authors' abstract)

HALL, D.L., STERNER, S.M. and BODNAR, R.J., 1989b, Experimental evidence for hydrogen diffusion into fluid inclusions in quartz (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A358. Authors at Dept. Geological Sciences, Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Synthetic CO_2-H_2O inclusions containing 50 mol % CO_2 were formed by healing fractures in quartz at 3 kbar and 825°C. Microthermometry and Raman spectroscopy proved that the inclusions contained *only* CO_2 and H_2O. Quartz disks containing these fluid inclusions were placed into cold-seal P vessels and annealed at 1.5 kbar and 650°, 750° or 825°C for 15 days (355-360 h). During annealing, H fugacity (fH_2) of the P medium was buffered at 100-250 bars by the assemblage graphite + methane. H fugacity in the fluid inclusions before reequilibration was ~4-5 bars for all three annealing T. At annealing conditions the inclusions were overpressured by 825-1500 bars, eliminating a potential driving force for leakage *into* the inclusions resulting from a gradient in total P.

Microthermometric analyses of annealed inclusions exhibit Tm CO_2 that are below the triple point T of pure CO_2 (-56.6°C) and average -57.9°, -64.5° and -65.4°C for the 650°, 750° and 825°C experiments, respectively. Th of the CO_2 phases decrease from an average of 28.1°C (to the liquid phase) prior to reequilibration to -52°C (to the vapor phase) after annealing at 825°C, and liquid CH_4 was observed below -84°C in the 825°C sample. Average Tm clathrate increase from 10°C prior to annealing, to 16.8°C after annealing at 825°C. Raman analyses of annealed inclusions indicate that they contain CH_4 and H_2 in addition to CO_2 and H_2O that were present before annealing experiments. CH_4 in annealed fluid inclusions is produced by reduction of CO_2.

Increased H diffusion rates at higher T result in larger amounts of H entering inclusions in a given amount of time and, concomitantly, larger compositional changes in inclusions annealed at higher T. Microthermometry and computed volumes of fluid phases indicate that $X(CH_4)$ correlates positively with T and support this conclusion. However, it is possible that the increase in $X(CH_4)$ reflects the increase in fH_2 with T along the graphite-methane buffer at constant P.

These results suggest that CO_2/CH_4 ratios present in inclusions from a variety of moderate to high T geologic environments may not reflect initial fluid compositions and, thus, cannot be used as monitors of fO_2 during inclusions formation. (Authors' abstract)

HALSOR, S.P., 1989, Large glass inclusions in plagioclase phenocrysts and their bearing on the origin of mixed andesitic lavas at Tolimán Volcano, Guatemala: Bull. Volcanol., v. 51, p. 271-280. Author at Dept. Earth and Environmental Sciences, Wilkes College, Wilkes-Barre, PA 18766.

Irregularly shaped, large and clear ("LAC") glass inclusions are present in plagioclase phenocrysts in several andesitic lavas erupted from Tolimán volcano, Guatemala. Their morphology is different from densely spaced, fine-grained glass inclusions that form concentric zones in dusty or cellular textured plagioclase phenocrysts. The large size of LAC inclusions make them suitable for microprobe analysis, and average bulk compositions are presented for glasses in 30 phenocrysts from eight lava samples. Their compositions are rhyolitic and in disequilibrium, or "out-range" (Anderson, 1976) with respect to whole-rock and groundmass glass compositions. LAC inclusions typically occur in large, tabular plagioclase phenocrysts with relatively uniform, sodic compositions (An 40-54). Compositions of feldspar phenocrysts not containing LAC inclusions range from An 41 to An 81. Petrographic and chemical data support a primary origin for LAC glasses, suggest mixing of mafic and silicic magmas, and also constrain a mechanism for magma mixing. Rapid growth of plagioclase and entrapment of LAC glass occurs during mixing in a vapor-rich silicic liquid under low degrees of undercooling. These conditions are possibly produced in a high-level magma body such as that envisioned by Huppert et al. (1982), where replenishment and subsequent crystallization of a hydrous magma induces density instability and mixing with the resident magma. (Author's abstract)

HAMES, W.E., TRACY, R.J. and BODNAR, R.J., 1989a, Determination of metamorphic pressure-temperature-time paths by a combined petrologic, fluid inclusion, geochronologic, and thermal modeling approach (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 31. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

For nearly two decades, FI studies combined with metamorphic petrologic techniques have recorded P-T (pressure-temperature) paths with nearly isothermal decompression followed by more isobaric cooling. Previous studies generally assumed a "reasonable" cooling rate in order to extrapolate these paths to P-T-t (time) paths, but this assumption negates the potential to critically evaluate processes which form these paths. We defined the Devonian

(Acadian) P-T path for part of the Connecticut Valley synclinorium, southwestern New England, and combined it with published mineral cooling ages to derive the P-T-t path. We then compared this path with those generated by 1-dimensional thermal models to more fully constrain the unroofing history. The P-T path has initially nearly isothermal decompression followed by more isobaric cooling, similar to paths defined by previous petrologic/FI studies. The T-t path indicates the net unroofing rate was extremely non-linear, initially at ~1.0 cm/yr and decreasing exponentially to ~0.3 mm/yr during isobaric cooling. The maximum uplift rate appears to have occurred over a 1-2 Ma interval, and is entirely consistent with modern (instantaneous) rates of uplift. This unroofing rate is essentially an order of magnitude greater than maximum rates based solely upon mineral cooling ages, but we believe this is because such rates are typically an average for a 10-20 Ma interval. The rapid unroofing occurred during the middle Devonian (Givetian) and slowed to less than 0.3 mm/yr by the end of the Devonian, and we believe that this differential uplift is recorded in Devonian intrusive activity and sedimentation. Intrusion of post-metamorphic pegmatites in southwestern New England was widespread during the middle Devonian, and we interpret these to have formed by partial melting of pelitic rocks during rapid decompression. The coarsest and thickest accumulations of sediment in the northern Catskill delta were deposited during the middle Devonian, and clastic deposition in this basin ceased by the end of the Devonian, which we interpret to reflect differential uplift and erosion following Devonian nappe emplacement. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p. 152. (E.R.)

HAMES, W.E., TRACY, R.J. and **BODNAR, R.J.**, 1989b, Postmetamorphic unroofing history deduced from petrology, fluid inclusions, thermochronometry, and thermal modeling: An example from southwestern New England: Geology, v. 17, p. 727-730. Authors at Dept. Geological Sciences, Virginia Poly. Inst. and State Univ., Blacksburg, VA 24061.

Nonlinear unroofing rates from ~10 to <1 mm/yr following high-P Acadian (Devonian) metamorphism have been documented in southwestern New England by using combined petrologic, fluid inclusion, thermochronometric, and thermal modeling techniques. Thermobarometry of pelitic schists from the Rowe-Hawley belt of western Connecticut indicates peak Acadian P-T conditions of 8.2 kbar and 575°C. Densities of CO_2- and H_2O-rich fluid inclusions require nearly isothermal decompression followed by more isobaric cooling from these conditions. Comparison of this observed path to those generated by thermal models suggests that decompression was characterized by initial rapid upward en bloc velocity (~1 cm/yr) of brief duration, followed by much slower unroofing rates ($\leq$0.3 mm/yr). Published geochronologic ages in this region constrain the rapid uplift to the Middle Devonian, and uplift slowed dramatically by the end of the Devonian. This differential uplift has major implications for interpretation of Devonian igneous activity and sedimentation in southwestern New England. (Authors' abstract)

See also previous item. (E.R.)

HAN, Gongliang, SUN, Minyun and **HE, Siwei**, 1989a, Geology and ore-forming mechanism of Yejiwei tin-polymetallic ore deposit in Dongpo ore field, Hunan province, China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-22-23. Authors at Bureau of Geology and Mineral Resources of Hunan Province, China.

The Yejiwei Sn-polymetallic ore deposit is located to the east of the Qianlishan granite. The quartz porphyry apophysis formed by the first intrusive activity occurs in the central part of the Yejiwei ore deposit. The apophysis intruded into limestone of the upper Devonian system. Because of skarnization, greisenization, and mineralization, the quartz porphyry Sn orebody of greisenization, the skarn Cu, Sn orebody and marble Sn, Be orebody of network of veins had been produced. There occurs nonsymmetrically annular skarn orebody closely around the quartz porphyry. The minerals of the veins are cassiterite, quartz, fluorite, sericite, topaz, tourmaline, taaffeite, chrysoberyl nigerite, zinc, and spinel. The quartz porphyry was altered strongly by ore-forming fluid. The main alterations are greisenization, and then sericitization and silicification. The greisenization can be divided into two stages: early greisenization in large-scale produced massive greisen; then later network greisenization, which superimposed the massive greisen and the skarn orebody. Clearly horizontal zoning of ore-forming elements occurs from the center to margin in the ore deposit. It is characterized by: Sn, W (in the orebody of quartz porphyry of greisenization) → Sn, Cu (in the skarn ore body) → Sn, Be (in the network type of marble orebody) → Pb, Zn (in the marble or limestone.

The results of the study indicate that five ore-forming stages can be distinguished in the deposit as follows: the early skarn stages, the later skarn stage, the pneumatolytic-hydrothermal stage, the mesothermal stage, and the low hydrothermal stage. There are four periods of boiling of the ore-forming fluid during the pneumatolytic-hydrothermal stage. The T of the four boiling periods are 438-389°C, 382-368°C, 354-335°C, and 303°C. The ore-forming fluid has higher salinity of 32.7% to 73.2% (wt %) and contains abundant Si^{4+}, Ca^{2+}, K^+, Na^+, F^-, CO_2, Cl^- and HCO^-_3. The ratios of K^+/Na^+ of the solution in every stage are basically constant. The fO_2 of ore-forming in the ore deposit decreases with decrease of the T of ore-forming process (lg fO_2 from -37.38 to -50.25). The values of P are low, ranging from 2-3 to 484 bars.

The $\delta^{18}O$ values of the quartz of Qianlishan granite range from +9.80 to +12.00% [sic]. The $\delta^{18}O$ values of the magmatic water of the granite range from +9.80 to +11.30%. The δD value of magmatic water obtained from quartz inclusion of the granite is 56%. The $\delta^{18}O$ values of the ore-forming hydrothermal water range from +9.81 to +7.51%. The authors hold that the ore-forming hydrothermal water is a mixed hydrothermal water formed from the mixing of magmatic water with meteoric water. The elements of W, Sn, Mo, Bi, Be, F, Cl, etc., chiefly derived from the granitic magma; Zn mainly came from strata of carbonate rock; Pb and S not only came from the granitic magma but also from the strata of carbonate rock. (From authors' abstract by E.R.) [sic; see p. 1]

HAN, Gongliang, SUN, Minyun and HE, Siwei, 1989b, Geology and ore-forming mechanism of the Yejiwei tin-polymetallic ore deposit in Dongpo ore field, Hunan Province, China: Progress in Geosciences in China (1985-1988)—Papers to 28th IGC, v. 1, p. 45-49. Authors at Bureau of Geology and Mineral Resource of Hunan Province, Changsha, China.

Apparently a longer version of the previous item. (E.R.)

HANNINGTON, M.D., SCOTT, S.D. and HERZIG, P.M., 1989, Geochemical controls of gold mineralization in massive sulfide deposits of modern ocean floor and their ancient analogs (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-24. Authors at Univ. Toronto, Toronto, Canada.

The measured slightly acid pH and high H_2S content (10^{-2} to 10^{-3} molal) of vent fluids, temperatures of 200°C to 300°C measured directly from Au-enriched vents and inferred from fluid inclusions, sulfur-rich assemblages accompanying Au enrichment, and laboratory experiments on Au solubility are all consistent with Au being transported as a bisulfide rather than a chloride complex. Au solubility can be described by a redox reaction. (From authors' abstract by E.R.)

HANSON, B., ULMER, G.C. and GOLD, D.P., 1989, Presence of poikilitic graphite in Merensky Reef at Brakspruit Shaft in Bushveld Igneous Complex (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-26. First author at Temple Univ., Philadelphia. PA.

Significant amounts of graphite are found associated with "pothole" structures in the Merensky Reef of the Bushveld Igneous Complex, Republic of South Africa. Poikilitic textures of graphite in silicate suggests that the graphite was present prior to the crystallization of the intercumulate phases in parts of the Merensky Reef.

SEM/EDS analysis of all the forms of graphite indicate the presence of significant amounts of chlorine residing in a yet-undetermined manner within the graphite. KCl and apatite(?) crystals have also been found in these botryoidal graphite samples. (From authors' abstract by E.R.)

HANSTEEN, T.H., 1989, Fluid and silicate melt inclusions in the Eikeren-Skrim peralkaline granite complex, the Oslo paleorift, Norway (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 45. Author at Mineral.-Geol. Museum, Sars gate 1, N-0562 Oslo 5, Norway.

The Eikeren-Skrim subvolcanic granite complex (271 ± 2 Ma) was emplaced at a late stage in the magmatic history of the Permo-Carboniferous Oslo paleorift. The complex consists of mildly peralkaline rocks, most of which are miarolitic. Several generations of fluids and solids occur as inclusions in rock-forming (magmatic) and miarolitic quartz. P magmatic inclusions comprise single mineral grains, grain clusters (±glass), and aqueous FI with salinities of 42-63 wt % NaCl eq. The crystallized silicate melt and magmatic brine inclusions coexist with vapor-rich FI with highly variable salinities, but without CO_2. This is interpreted as evidence of super-solidus fluid unmixing. Crystallized silicate melt inclusions show incipient melting at 685-705°C, which is interpreted as the solidus of the granite. Large amounts of magmatically derived fluids were retained in the miarolitic cavities at sub-solidus conditions. Salinities remained above 40 wt % NaCl eq. down to 450°C, without the influence of fluid unmixing. Combined energy-dispersive X-ray analysis and laser Raman microprobe analysis reveals that aphthitalite,

$(K,Na)_3Na(SO_4)_2$, occurs as a dm in most magmatically derived FI. Fluid unmixing involving minor amounts of CO_2 occurred on a regional scale in the granite at 412 ± 51°C, and involved fluids with salinities of 47 ± 7 eq. wt % NaCl. This gives a hydrostatic P estimate of 250 ± 60 bar. Below about 400°C, the fluids were rapidly diluted through mixing with external fluids. Inclusion properties indicate a nearly isobaric cooling path at quasi-lithostatic P down to about 500°C, followed by a rapid decompression and adjustment to hydrostatic P at 412 ± 51°C. (Author's abstract)

HARLOW, G.E., 1989, Potassium in clinopyroxene inclusions in diamond (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A240-241.

HARRIS, Chris, 1989, Oxygen-isotope zonation of agates from Karoo volcanics of the Skeleton Coast, Namibia: Am. Mineral., v. 74, p. 476-481. Author at Dept. Geochem., Univ. Cape Town, Rondebosch 7700, South Africa.

Oxygen-isotope profiles through six agates from Sarusas, in the Skeleton Coast Park, Namibia, show that $\delta^{18}O$ varies from 20.4‰ to 28.9‰. These values are consistent with low T of formation. Systematic differences in $\delta^{18}O$ exist between coarsely crystalline quartz (Q) bands and microcrystalline quartz (MQ) zones within the same agate, with the Q zones being, on average, 3‰ lighter than MQ zones. This difference is consistent with the crystallization of Q zones from H_2O vapor and MQ zones from H_2O liquid at about 120°C. Boiling hydrous fluids at P just higher than 1 atm should be expected at shallow levels in a cooling lava pile. A T of formation of 120°C requires that the depositing fluids were enriched in ^{18}O relative to present-day meteoric waters. Enrichment of meteoric fluid in ^{18}O probably occurred as the result of prolonged boiling and loss of vapor rather than exchange with the host Karoo volcanics. (Author's abstract)

HARRIS, Nigel, 1989, Carbon dioxide in the deep crust: Nature, v. 340, p. 347-348. Author at Dept. Earth Sciences, The Open Univ., Walton Hall, Milton Keynes MK7 6AA, U.K.

A discussion of paper by Peterson and Newton (this issue). (E.R.)

HARRIS, N.B.W. and **BICKLE, M.J.**, 1989, Advective fluid transport during charnockite formation: An example from southern India: Earth Planet. Sci. Lett., v. 93, p. 151-156. First author at Dept. Earth Sciences, The Open Univ., Milton Keynes, MK7 688, U.K.

Isotopic studies of incipient charnockite formation in southern India suggest that isotopic shifts in $\delta^{13}C$ do not coincide with the dehydration reaction front. The relative velocities of the dehydration reaction front and the C isotopic front may be calculated assuming that their propagation is due to advection of an infiltrating CO_2-rich fluid. The velocity of the reaction front is a function of the fluid flux rate, the difference in CO_2 content of the fluid phase across the front and the volume rate of H_2O production by the dehydration reaction. The velocity of the C isotopic front is also a function of the fluid flux rate, as well as the CO_2 content of the fluid and the graphite content of the gneiss.

Using modal and mineral composition data from a graphite-bearing incipient charnockite in southern India we calculate that the C isotope front has propagated at about twice the velocity as that of the reaction front. Separation between reaction and C fronts constrains the distance over which propagation has occurred; preliminary data suggest that in some charnockite localities from southern India, infiltration occurred over a limited distance (<2 m), and the minimum fluid/rock volume ratio required for advective propagation of the C front in graphite-bearing localities is about 0.1. (Authors' abstract)

HARTMETZ, C.P. and **GIBSON, E.K., Jr.**, 1989, *In situ* determination of volatiles in CM2 chondrites (abst.): 52nd Annual Meeting of the Meteoritical Society, Vienna Austria, July 31-August 4, 1989, Abstracts and Program, LPI Contribution 712, p. 81. Authors at Planetary Sciences Branch, NASA-JSC, Houston, TX 77058.

HARUNA, M., UENO, H. and OHMOTO, H., 1989, Paragenesis and fluid inclusion study of skarn formation and ore mineralization at the Tengumori deposit, Kamaishi mine (abst.): Min. Geol., v. 39, p. 62-63 (in Japanese, translated by S. Taguchi). Authors at Tohoku Univ.

The Tengumori deposit is rather different from other skarn deposits in the Kamaishi mine; it is embedded in Permian limestone along the unconformity between the limestone and Cretaceous sandstone. There is a zonal arrangement of the skarn minerals from bottom to top: limestone → garnet ($\text{And}_{95\text{-}}$) + monoclinic pyroxene skarn → garnet ($\text{And}_{40\text{-}60}$) + monoclinic pyroxene skarn → weakly skarn altered sandstone. Hydrothermal activities are divided into three stages: calc-silicate, ore mineralization and calcite stages; Th and salinities of these three stages are 264-313°C and 5.8-17.7 eq. wt % NaCl; 160-306°C and 4.1-9.9 eq. wt % NaCl; and 138-230°C and 1.0-23.4 eq. wt % NaCl, respectively. Mineral occurrence and the fluid inclusion thermometry indicate that the deposit formed along the unconformity with the cap rock of sandstone, with iron of the sulfides originally from monoclinic pyroxene. (Authors' abstract)

HASENOHR, E.J. and DUMMETT, H.T., 1989, Geology and fluid inclusion analysis of the Newsboy deposit, Maricopa County, Arizona (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A295. First author at Dept. Earth Sciences, Dartmouth College, Hanover, NH 03755.

Au and Ag mineralization at the Newsboy deposit is associated with a low-angle detachment fault that places a Tertiary-age felsic volcanic sequence over mafic schist and gneiss of Precambrian age. Ore-grade mineralization occurs within interbedded rhyolitic flows, tuffs and volcaniclastic rocks that are intensely silicified and in part brecciated in a zone along and adjacent to the detachment fault. Au and Ag mineralization also is present in silicified structures that are interpreted as listric faults related to the detachment faults. High-angle normal faults cut and offset the detachment fault and the mineralization.

Hydrothermal alteration assemblages recognized within the rhyolitic volcanic rocks at Newsboy include quartz-kaolinite-alunite, kaolinite-iron oxide, and silica. With respect to the zone of ore-grade Au-Ag mineralization, the quartz kaolinite-alunite assemblage is uppermost and is underlain by the kaolinite-iron oxide assemblage. The silica assemblage is spatially and apparently genetically most closely associated with the mineralization. It includes, from earliest to latest, pervasive silicification of the volcanic rocks in a zone above the Precambrian contact, yellow-green chalcedony in the detachment fault and associated listric faults, veins and veinlets of white, banded opaline quartz, and rare amethyst. Veins and irregularly-shaped zones of black, manganiferous calcite cut the silicified volcanics.

Heating/freezing analysis of fluid inclusions in quartz from banded quartz-chalcedony veins associated with the Au-Ag mineralization indicates that ore-forming fluids were of low to moderate T (average = 236°C) and low salinity (average = 3.0 wt % NaCl eq.). (Authors' abstract)

HASLAM, H.W., 1989, Charnockites at Mchinji, Malawi: The nature and origin of igneous charnockites: J. African Earth Sci., v. 8, no. 1, p. 11-18. Author at British Geol. Surv., 67-78 Gray's Inn Road, London WC1X 8NG, U.K.

Igneous charnockites constitute a distinctive group of rocks, differing in nature and in mode of formation from non-charnockitic orthopyroxene-bearing granites on the one hand and from metamorphic charnockites on the other. Charnockites at Mchinji, and at other localities in Africa, are unmetamorphosed magmatic rocks emplaced about 1100 Ma ago in intracratonic collision zones. They owe their charnockitic character (orthopyroxene; thin, coloured veinlets and films along grain boundaries and fractures; and dark aspect) to the fact that they were formed by consolidation of a water-deficient, CO_2-rich magma. The primitive chemistry of the Mchinji charnockites suggests a mantle origin for the parent magma, followed by limited fractional crystallization to yield the more evolved members of the suite. The orthopyroxenes are ferrohypersthenes, with unusually high Fe values for igneous orthopyroxenes, and high Mn and low Al compared with orthopyroxenes in metamorphic charnockites. The biotites have low Al^{vi}, a typical igneous characteristic. The amphiboles are iron-rich potassium hornblendes. The almandine garnets, with moderate Ca and Mn but low Mg, are typical neither of metamorphic charnockites nor of granites. (Author's abstract)

Includes a short discussion of the evidence of volatiles (p. 16). (E.R.)

HAWTHORNE, F.C. (ed.), 1988, Spectroscopic Methods in Mineralogy and Geology: Reviews in Mineralogy, Vol. 18, 698 pp., Mineralogical Society of America.

HAYASHI, K.I., 1989, Importance of Zn- and Ag-sulfide complexes in formation of epithermal precious metal deposits (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-43.

HAYES, T.S., 1989, A survey study of fluid inclusion microthermometry, Spar Lake strata-bound copper-silver deposit, Belt Supergroup, Montana (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A250. Author at U.S. Geological Survey, Box 25046, Denver Federal Center MS 905, Denver, CO 80225. [Note: Verbal presentation cancelled. (E.R.)]

Fluid inclusions found in ore-stage authigenic quartz, carbonate, and albite at the Spar Lake deposit still record ore-stage conditions despite post-ore burial metamorphism at >325°C. Quartz overgrowth and carbonate were either ore synchronous or slightly pre-ore, and albite was either ore synchronous or post-ore, all part of a zoned system of Revett formation sandstone cements that includes the ore sulfides. Ore-stage microtextures and microzonations are preserved in these and other ore-stage cements.

Ore-stage fluid inclusions are <5 μ in size and occur as isolated, two-phase, liquid-vapor (L-V) inclusions containing tiny gas bubbles or as one-phase liquid (L) inclusions. The L inclusions may be metamorphically homogenized and stretched equivalents of the L-V's [sic], or they may have been trapped at near-ambient T.

L-V inclusions homogenize to liquid at a range of T varying from 74°C, in the fringing galena-calcite zone, to more than 175°C in orebody bornite-calcite and chalcocite-chlorite zones. No Th <130°C are found in the orebody, and no Th >130°C are found in the fringe galena-calcite zone. All Th and salinities (S's) also decline from the orebody across the chalcopyrite-ankerite zone, so that this zone could not have been a feeder. Instead, it was an ore-stage, thermal equivalent in pre-ore hematitic sandstone of the chalcopyrite-calcite and galena-calcite zones that formed in pre-ore pyritic sandstone. Ore fluids must have fed from below.

L-V inclusions in authigenic albite from the newly described albitic zone have Th ≥ 160°C and have S's ≥ 10 wt % eq. NaCl. The albitic zone lies on a projection of mineral zoning towards a hypothetical ore fluid source from both the chalcopyrite-ankerite and chalcocite-chlorite zones. Anomalously low Cu contents suggest that the albite zone was a major source of metals for Revett-hosted deposits. (Author's abstract)

HAYNES, F.M., BEANE, R.E. and **KESLER, S.E.**, 1989, Simultaneous transport of metal and reduced sulfur, Mascot-Jefferson City zinc district, East Tennessee: Evidence from fluid inclusions: Am. J. Sci., v. 289, p. 994-1038.

Fluid inclusion compositional data from the Mascot-Jefferson City Zn district of East Tennessee and equilibrium solubility calculations for dolomite and sphalerite are shown to be consistent with simultaneous transport of Zn and sulfide S. Scanning electron microscopy and energy dispersive analysis of sphalerite-hosted fluid inclusion decrepitates establish that the solutions attending sulfide deposition were Na-Ca chloride brines with subordinate K and Mg. Integration of the cation data obtained from the decrepitate analyses with final melt T of fluid inclusions permits the determination of individual ion molalities for Na (2.2-3.4 m), Ca (0.3-0.8 m), K (0.1-0.3 m), and Mg (0.04-0.12 m) and documents the presence of three chemically distinct solutions within the solution collapse breccias that host ore. Ca/Na ratios, which were greater in ore-stage assemblages than in earlier non-sulfide assemblages, are thought to record the progressive evolution of basinal brines during diagenesis and mineralization. Ca/Mg ratios were not readily distinguishable among the three solutions; their range, from 4:1 to 7:1, indicates equilibrium with ordered dolomite rather than calcite. The Ca and Mg composition data, in conjunction with inclusion CO_2 abundances of 0.4 to 1.5 mole % as determined by gas chromatography, indicate that two of the solutions documented by the inclusion data would be in equilibrium with dolomite at pH's below 4.0, conditions that would permit mutual transport of considerable Zn and S.

Solution collapse breccias hosting mineralization apparently formed when these brines dissolved and dolomitized limestone units of the Lower Ordovician Knox Group. Ore-matrix breccia bodies surround and post-date coarse rock-matrix breccias which contain appreciable "recrystalline" dolostone but are devoid of sphalerite. It is proposed that during the Devonian-Mississippian when the Knox was still deeply buried (3-4 km), sphalerite deposition resulted from T decrease and perhaps pH increase associated with the release of "abnormal" fluid P generated during sedimentary basin evolution. Unmineralized breccia cores are interpreted to result from pH-independent dolomitization of limestone by the corrosive ($pH < 4$), "abnormally" pressured brines prior to P release and T drop. Sphalerite banding suggests that either the degassing was accomplished in several, discrete steps, or that CO_2-charged, pregnant solutions were introduced episodically into the district. (Authors' abstract)

HAYNES, F.M. and **SCHRIJVER, Kees**, 1989, Fluid-inclusion evidence of copper remobilization during retrograde metamorphism in the central Labrador Trough: Can. Mineral., v. 27, p.23-40. First author at Geol. Dept., Exxon Co. U.S.A., 225 West Hillcrest Dr., Thousand Oaks, CA 91360.

Major-element compositions of decrepitates of individual FI determined by scanning electron microscopy and energy-dispersion analysis of some representative Cu-sulfide-bearing quartz-dolomite veins in the Dunphy dolostone of the central Labrador Trough indicate mineral deposition at 350 ± 50°C from highly saline (36-42 eq. wt % $NaCl + CaCl_2$) reduced solutions carrying 0.1 to 1.0 m total S and in excess of 300 ppm total Cu. The pH of these fluids has been calculated to be 4.4 ± 0.8, with oxygen fugacities ranging from 10^{-30} to 10^{-28}. Fluid P attending mineral growth in the veins (about 1 kbar) were considerably less than the 2.5-3.0 kbars proposed for peak greenschist-grade metamorphism. Early, diagenetic Cu-sulfide minerals within the Dunphy dolostone were leached by saline, retrograde metamorphic fluids. Sulfides (bornite + digenite + covellite ± chalcopyrite ± pyrite) were then reprecipitated in fractures within the same strata, perhaps during unloading of the region after the Hudsonian Orogeny. (Authors' abstract)

HÄNNI, H.A. and **WEIBEL, M.**, 1989, Examination of the cat's-eye effects of heat-treated zircon from Sri Lanka: Z. Dt. Gemmol. Ges., v. 38, no. 2/3, p. 95-101 (in German, English abstract).

After undergoing heat-treatment, certain zircons from Sri Lanka exhibit a cat's-eye effect. The oriented inclusions which promote the chatoyancy are very fine fissures crystallographically oriented parallel to the c-axis and which apparently lie in the planes (100) and (010). Prismatic crystals of about 1 micron length were found in the centre of some of the disc-shaped fissures (diameter ~15 microns). The Ca-content and the amorphous nature of these crystals indicate that they are thermally decomposed apatite. (Authors' abstract)

HE, Zhili, 1989, Au-Pb-quartz vein ore district (A new type of lead ore deposit in China): III-rd Soviet-Chinese Symposium "Geology and Ecology of Amur Basin," Abstracts, v. II, p. 32-34, Blagoveshchensk, U.S.S.R.

Dong Chuang Au-Pb-quartz vein deposit is one of the most important ore deposits in the famous Xiaoqinlingshan Au field. It is a large Au deposit and middle-size Pb deposit, in which there is much Ag. The parallel ore-bearing quartz veins are controlled by E-W striking faults in the Archean Taihua Group metamorphic rocks. Main mineralization can be divided into four stages: I pyrite-quartz; II quartz-pyrite; III carbonate-galena (plus minor sphalerite and chalcopyrite); IV carbonate-quartz. II and III are main Au (as Au and electrum) stages. Wall-rock alteration is represented mainly by pyritization, sericitization, silicification, carbonation and chloritization. Ore-forming fluid is believed to be deep metamorphic water, possibly plus magmatic and meteoric water. Fluid inclusion studies on hydrothermal quartz show that the main range of T = 200-200°C, P = 1324-1800 bar, average = 1570 bar. Ore-forming solution is rich in CO_2.

This ore deposit is similar to many Au-quartz vein ore deposits in metamorphic rocks from all over the world in many ways. But its important characteristics is [the high Pb content; it is] a new type of Pb ore deposit in China. (From author's abstract by E.R.)

HE, Zhili, HU, Jie, YANG, Maoyuan and **YU, Xiaojin**, 1988, Genesis of Liancheng manganese ore deposit in Fujian Province of China: Int'l Symposium "Deep Structure of the Pacific Ocean and its Continental Surroundings," Abstracts, p. 25-27, Blagoveshchensk, U.S.S.R.

Discusses briefly various aspects of this ore deposit, alteration, weathering, mineralogy, trace elements, S isotopes, and fluid inclusions which have Th 179-229°C. (E.R.)

HE, Zhili and **YANG, Zhenglin,** 1989, Preliminary study of physico geochemical condition of the mineralization of Jinchangyu gold deposit in Hebei, China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-44-45. Authors at Beijing Univ. of Science and Technology, P.R.C.

The geneses of these ore deposits have been argued for many years. (...) Faults and joints are developed, and the fissures have been filled and replaced by Au-bearing quartz veins. They formed complex ore veins. The formation stage of the Au-bearing quartz veins can be divided into four stages. Quartz veins from the third stage are very important. In the early part of the third stage, pyritization is weak but galena and chalcopyrite can be found in quartz veins. In the late part of the third stage, pyritization and other wall rock alterations are strong. Most large orebodies are related to these quartz veins.

Jinchangyu gold ore deposits are related to hypothermal-mesothermal solution. However, the main orebodies probably were from hypothermal solution. There are typically high-T minerals (magnetite and molybdenite) in this area. The conditions of physical geochemistry during mineralization of these samples are: $T_t = 274\text{-}495°C$; $P_t = 440\text{-}573$ bars; $fO_2 = 2.75 \times {}^{-30}\text{-}1.26 \times 10^{-36}$ bars; pH = 4.58-4.78; Eh = -0.75 - 0.72(v). The major components in hydrothermal fluid are: gas phases (mg/1000 g quartz sample): $CO_2 = 4.96\text{-}121.90$; $H_2O = 628.47\text{-}1264.64$; $N_2 = 0.000\text{-}6.235$; $CH_4 = 0.159\text{-}0.695$; CO = 1.614-2.450; liquid phases (g/10 g quartz sample): Na^+ - 7.76-51.24; $K^+ = 7.50\text{-}37.36$; $Mg^+ = 0.00\text{-}0.31$; $F^- = 0.75\text{-}1.69$; $Cl^- = 5.12\text{-}24.50$Jinchangyu gold ore area is similar to the Linglong gold area in many ways (Table I), for example, type of deposit, Th, Pt, CO_2 contents of fluid inclusions, wall rock alterations, and some ore hunting indicators. The character of the Au-bearing vein quartz is the high CO_2 content in inclusion fluid. It is very different from that of the barren vein quartz. CO_2 content in fluid inclusion in quartz is one of the ore hunting indicators.

It is necessary to continue studying the origin of ore-forming solution in this area. (Authors' abstract)

Table 1. Comparison of ore-forming conditions between Jinchangyu gold area and Linglong gold area

Jinchangyu gold area, Hebei, China		Linglong gold area, Shangdong,China	
Type of ore deposit	Gold-bearing quartz Vein;Main mineralization is related to hypothemal solution	Type of ore deposit	Gold-bearing quartz vein;Mineralization is related to hypothemal-mesothemal solution
Th, °C	235-388	Th, °C	230-380
Tt, °C	274-459	Tt, °C	
Pt, bar	440-573	Pt, bar	182-557
CO_2wt%	3.4-16.2	CO_2wt%	5-10
Na^+wt%	0.09 -0.32	Na^+wt%	0.12-0.46
K^+wt%	0.22-0.30	K^+wt%	0.12-0.16
Mg^{2+}wt%	0.000-0.004	Mg^{2+}wt%	0.14
Cl^-wt%	0.062-0.233	Cl^-wt%	0.7-2.1
Mineralization period	Yanshanian movement period,Fuping movement period	Mineralization period	Yanshanian movement period
Wall rock	plagioclase-hornblendite	Wall rock	granite
Wall rock alterations	Pyritization,sericitization,albitization, silicification and carbonation	Wall rock alterations	Phritization,sericitization,potash feldsparization,silicification, carbonation,chloritization and kaolinization
Associated minerals*	Main gold minerals: Native gold and calaverite. Associated minerals:Py,Moly,Ga, Sph,Chal,PR,M and Mel; Q, Naf, S, Cal, Dol and Ru	Associated minerals	Main gold minerals: Native gold and electrum.Associated minerals: Py, Ge, Sph & Chal. Q, Kf, S and Cal.
Notes	Pyritization and the quartz rich in CO_2 can be used as more important ore hunting indicators	Notes	Pyritization and the quartz rich in CO_2 can be used as more important ore hunting indicators

* Py-Pyrite; Moly-Molybdenite; Ge-Galena; Sph-Sphalerite; Chal-Chalcopyrite; PR-Pyrrhotite; M-Magnetite; Mel-Melonite; Q-Quartz; Naf-K-feldspar; S-Sericite; Cal-Calcite; Dol-Dolomite; Ru-Rutile; Kf-K-feldspar.

HE, Zhili, XU, Jiuhua and YANG, Zhenling, 1989, Preliminary study of geophysical and geochemical conditions for gold metallogenesis of Dongchuang gold mine in Xiaoqinling: Proc. Int'l Symposium "Gold Geology and Exploration" (ISGGE), p. 719-722, Shenyang, China.

Au mineralization is related to intrusion of the granite. The hydrothermal ore-forming epoch may be subdivided into four stages [as evidenced by] the major features of pyrite [and quartz from the various stages (Tables 1 and 2)].

The features of inclusions in quartz at various stages are shown in Table 3. Fluid inclusions are abundant in quartz, consisting mostly of CO_2 inclusions, which is favorable to the detection of ore-forming pressure. According to the P shown in Table 3, it is inferred that the minimum ore-forming depth should be 4.81 km and [hence this a] plutonic Au ore deposit.

Analyses of inclusion composition are as follows: δDH_2O = -37.3-48.0, composition for fluid phase (g/10 g quartz sample[1]): Na^+ = 32.47~63.63; K^+ = 4.09~5.88; Ca^{2+} = 1.05~3.22; Mg^{2+} = 0.07~0.19; F^- = 0.24~0.58; Cl^- = 51.41 ~86.67; SO_4^{2-} = 56.36~57.76. Composition for gas phase (1/g quartz sample[2]): CO_2 = 20.5~134; CH_4 = 0.0~13.4; $H_2O(l)$ = 0.23~4.02; molecular ratios: (CO_2/H_2O) = 0.011~0.14; (CH_4/H_2O = 0.0~4.17×10^{-3}). In addition, the composition (1/g sample[2]) for gas phase inclusion obtained from a quartz vein specimen of Wenyu rock body is: 88.0 (CO_2), 0.36 (CH_4), 1.6 (H_2O), molecular ratios CO_2/H_2O = 0.044, CH_4/H_2O = 0.238×10^{-3}.

The range of wall rock alteration contiguous to ore deposit is from 0 m to 30 m, as represented mainly by silicification, sericitization, pyritization and next to them are potash feldsparization, biotitization, epidotization, chloritization, carbonatization and sodium lime-epidotization.

Table 3. Characteristics of inclusions contained in quartz and ore-forming fluids.

Features	Stage			
	I	II	III	IV
size	n m-30 m	n m-30 m	5 m-40 m	10 m-35 m*
type	mostly as CO_2 inclusions	usually as CO_2 inclusions	mostly as CO_2 inclusions	mainly as CO_2 inclusions
phase when homogenized	gas	gas or fluid	mostly gas, sometimes fluid, occasionally critical phase	fluid
CO_2 proportion	high	medium	higher	low
Th C	220-360 (240-300)**	200-280 (220-260)	160-280 (200-240)	183-277 (200-220)
Pt. C		1324-1800***	1570 average	
P g/cm†	0.74-0.94	0.8-0.94	0.76-0.96	0.9-0.96
Tt. C	340-560 (390-450)	330-472 (375-415)	286-472 (348-390)	315-410 (348-375)
Sal††	2.6-11.2; 66 average[3]	3.3-9.9; 7.8 average	4.4-8.6; 7.2 average	8.2-8.6; 8.4 average
Eh (v)	-7.0; -0.76		-0.5 ~ -0.55 -0.50	

*, **, and *** not identified in original. (E.R.)
†"P" refers to density. ††Sal = wt % NaCl eq. (E.R.)

The isotopic values for O and S suggest metamorphic water, plus probably meteoric and magmatic compliments. The Pb came from old rock lead.

Characteristics of pyrite and quartz and CO_2 in inclusions may serve as ore guides. The ratios CH_4/CO_2, Ag/Au, and Ag/Pb suggest direction of ore fluid movement. (From authors' abstract by E.R., plus E.R.)

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[1] Sic. Probably should be μg/10 g?
[2] Sic. Probably should be μl/g?
[3] Sic. Probably should be 6.6?

[Note: A reprinted version of this abstract, provided by the author, corrects these two units as shown. Under "Type," however, all four are listed as "CO" rather than "CO_2." (E.R.)]

HE, Zhili, YUAN, Huaiyu and XU, Jiuhua, 1989, Fluid inclusion geochemistry in minerals obtained from Zhao-Ye gold metallogenetic belt, Shandong Province: J. Geochem. Explor., v. 33, p. 121-133. Authors at Dept. Geology, Beijing Univ. Science and Technology, Beijing, P.R.C.

A large number of fluid inclusions are observed in quartz contained in Au ores. A study of the geochemistry of inclusions from the Linglong Au deposit in Shandong Province shows that ore-forming T and P, frequency of appearance [of?] critical inclusions, and saline halo of the main Au-bearing veins 108 and 51 increase in the direction of Linglong Fault. We concluded accordingly, that: (1) the Linglong Fault was a conduit structure for mineralization and will form a favourable place for prospecting where the fault intersects a host structure trending east-northeast; (2) distinct differences in geochemical characteristics are present [as evidenced by] the fluid inclusions contained in Au-bearing quartz veins and barren quartz veins, with the former having higher Th frequency of appearance at critical inclusions, content of CO_2, H_2 and CH_4, and molar concentration ratio of $(H_2 + CH_4)$ to CO_2, than those of the latter; (3) decrepitation curves for the two sorts of quartz veins have obviously different characteristics; and (4) geochemical characteristics of fluid inclusions present in the quartz of quartz-vein-type Au ore deposits demonstrate that its metallogenetic P, salinity, and Td all increased progressively towards the deeper part of the quartz vein, approximating those of altered-rock-type Au ore deposits. We already know of some Au mines where quartz-vein-type Au ore deposits are turned at depth into altered-rock-type Au ore deposits. Therefore, attention should be paid to prospecting for altered-rock-type Au ore deposits below the quartz-vein-type. From this study, we believe that the geochemical study of fluid inclusions in minerals is a new and useful exploration approach, which should be further explored and used. (Authors' abstract)

HEARN, P.P., Jr., BELKIN, H.E. and SUTTER, J.F., 1989, Tectonically induced fluid migration in sedimentary basins: A new factor to be considered in the assessment of thermal history (abst.), *in* A.P. Schultz, ed., Appalachian Basin symposium: U.S. Geological Survey Circular 1028, p. 1.

Same abstract as in Fluid Inclusion Research, v. 21, p. 151-152. (H.E.B.)

HEARN, P.P., Jr., SUTTER, J.F. and BELKIN, H.E., 1989, Authigenic K-feldspar—An indicator of the geochronology and chemical evolution of mineralizing fluids in sediment-hosted lead and zinc deposits (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-46-47. Authors at U.S. Geological Survey, Reston, VA.

See Hearn et al., 1987a, Fluid Inclusion Research, v. 20, p. 163. (E.R.)

HEDENQUIST, J.W. and BROWNE, P.R.L., 1989, The evolution of the Waiotapu geothermal system, New Zealand, based on the chemical and isotopic composition of its fluids, minerals and rocks: Geochim. Cosmochim. Acta, v. 53, p. 2235-2257. First author at Mineral Resources Dept., Geol. Surv. of Japan, 1-1-3 Higashi, Tsukuba, 305, Japan.

The Waiotapu geothermal system is hosted by silicic rocks of the Taupo Volcanic Zone, New Zealand. Exploration drilling in the late 1950s down to 1100 m provided physical information on the system. Measured T show a boiling profile to 295°C, with shallow inversions, particularly in the north. Total discharge fluid samples were collected; the geothermometry and measured T show that fluids derive mainly from a shallow (~400 m deep) reservoir at ~225°C.

Petrologic study of drillcore samples recovered from seven wells reveals an alteration assemblage of quartz and albite + adularia, with a variable distribution of chlorite, pyrite, calcite, zeolites, epidote, pyrrhotite, sphene, leucoxene, apatite and minor base metal sulfides; white mica is a late overprint, particularly well developed at shallow depths. Surficial alteration of kaolin, cristobalite, alunite and smectite clays reflect alteration by acid sulfate, steam-heated waters.

The activities of components in minerals (determined from microprobe analyses and composition-activity relations) and fluids (speciated to reservoir conditions) indicate equilibrium now exists between the fluids and white mica; the Na/K ratio of the fluid is being controlled by dissolution of albite and adularia, while its H_2/H_2S ratio is buffered by pyrite replacing pyrrhotite. The fluids are now slightly undersaturated with respect to calcite.

The present deep fluids boil adiabatically from at least 300°C to 230°C; at depths of $\leq$500 m, this ascending chloride fluid is variably diluted by a steam-heated water (of zero chloride) that lies over, and occurs on the margin of, the system like a discontinuous umbrella; the steam-heated water is relatively CO_2-rich ($\leq$0.1 m). The cooling at shallow levels by this mixing has shifted the alteration from albite-adularia stability to white mica stability; this shift is enhanced by the CO_2-rich nature of the diluent.

Dilution of ascending chloride fluids by shallow waters is also supported by the oxygen and hydrogen isotopic composition of the mixture, with the deep fluid being enriched in $\delta^{18}O$ and δD from local meteoric by ~7 and 10‰, respectively. The patterns in whole rock $\delta^{18}O$ indicate that they were largely shifted in isotopic composition prior to incursion of steam-heated waters (possibly induced by a series of hydrothermal eruptions ~900 years ago). In contrast, the $\delta^{18}O$ composition of late vug calcite indicates its formation is related to the initial incursion of steam-heated groundwater and subsequent cooling; this is supported by fluid inclusion evidence. The δD shift from local groundwater composition, and the $\delta^{13}C$ composition of CO_2 determined from calcite (-4 to -6‰), may be evidence for a magmatic input to the meteoric convection cell.

The shallow portion of the Waiotapu geothermal system has recently evolved, both chemically and physically, by incursion of fluids from a steam-heated carapace. Continued refluxing of these relatively cool, hybrid fluids progressively deeper (with their "recycled" CO_2 content) will hasten hydrolytic leaching (in contrast to a single pass of adiabatically cooling deep fluids). This action, accompanied by argillic alteration, may eventually seal the deeper portions of the system, hastening its demise. There is evidence for similar events occurring in the fossil environment at epithermal depths. (Authors' abstract)

HEIDE, Klaus, 1989, Structural features of natural glasses and their correlation to the glass-forming processes: Chem. Erde, v. 49, p. 287-295 (in German, English abstract). Author at Otto-Schott-Institut der Sektion Chemie, Friedrich-Schiller-Universität Jena, DDR.

Detailed microscopic studies of natural glasses from various terrestrial environments show that the structural features of glasses differ strongly. By means of differential phase contrast, microscopy differences were detected in the homogeneity of different glasses on a microscopic scale. A correlation to the magmatic, metamorphic or sedimentary glass-forming processes seems possible. The changes of the structural features of glasses as a result of a controlled thermal treatment allow to set some limits in respect to the glass-forming conditions. In the case of the lechaterlierite inclusions in Moldavites, a small movement of bubbles and surprising mobility of the thin "hair-pin" was observed after treatment of the specimens at 1200°C under high vacuum conditions. (Author's abstract)

HEIN, U.F., 1989a, The genesis of the Gakara bastnaesite-monazite deposits: Evidence from fluid inclusions (abst.): Terra Abstracts, v. 1, p. 34. Author at FG Petrologie, Tech. Univ. Berlin, FRG.

The Gakara bastnaesite-monazite deposits, 20 km southeast of Bujumbara in the Republic of Burundi, are located in a Precambrian gneiss-granite-pegmatite complex. the mineralization is of vein- and stockwork-type and crosscuts the youngest granitic pegmatites, which are dated at 969 ± 8 Ma.

Bastnaesite, minor sulfides, and barite were deposited during an early vein stage which was accompanied by potassic alteration of the host rocks. Fluid inclusions in early smokey quartz and in bastnaesite contain high density CO_2-rich liquids and highly saline aqueous solutions which were trapped heterogeneously. In aqueous multiphase inclusions, the most important soluble salt minerals are, in order of their abundance, halite, arcanite (K_2SO_4), and sylvite. Chemical variation of the fluids during the early stage is indicated by differing Fe-dms (siderite, pyrite, goethite/hematite). Anhydrite and trapped muscovite complete the inclusion paragenesis defining the aqueous fluid composition to reside in the system Na-K-(Fe-Ca)-Cl-S.

The composition of the early fluids makes a genetic relationship with younger alkaline intrusives and carbonatites more probable. (From authors' abstract by E.R.)

HEIN, U.F., 1989b, The composition of the early fluids in the bastnaesite-monazite deposits of Gakara/Burundi (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 46. Author at FG Petrologie, Tech. Univ. Berlin, FRG.

The Gakara bastnaesite-monazite deposits, 20 km southeast of Bujumbara in the Republic of Burundi, are located in a Precambrian gneiss-granite-pegmatite complex. The youngest pegmatites, which are related to post-Kibaran granites, are dated at 969 ± 8 Ma. The mineralization is of vein- and stockwork-type and crosscuts these pegmatites.

Bastnaesite, minor sulphides, and barite were deposited during an early vein stage which was accompanied by potassic alteration of the host rocks. Following brecciation, bastnaesite was partially altered to monazite by selective phosphatization, while barite underwent partial silicification. These late processes cannot be traced by FI.

PS and some S inclusions in early smoky quartz, as well as P inclusions in bastnaesite, contain high density CO_2-rich liquids and highly saline aqueous solutions. These were trapped heterogeneously in two types of FI: (i) *Type 1 inclusions* are predominately liquid CO_2. In a few cases a small rim of aqueous solution is visible although probably always present. Tiny dxls are rare. (ii) *Type 2 multiphase inclusions* comprise highly saline aqueous fluids. These contain an aqueous solution, a gas bubble, commonly an opaque mineral and up to seven transparent solids.

The most important soluble salt minerals, in order of their abundance, are halite, arcanite (K_2SO_4), and sylvite. Chemical variation of the fluids during the early stage is indicated by differing Fe-dms: siderite is restricted to early inclusions in quartz; pyrite can be observed in quartz and bastnaesite respectively, and goethite/hematite occurs in S inclusions in bastnaesite. Anhydrite and trapped muscovite complete the inclusion solid phase assemblage. This assemblage indicates that the early aqueous fluids belong to the system Na-K-(Fe-Ca)-Cl-S. The composition of the early fluids probably indicates a genetic relationship with younger alkaline intrusives and carbonatites. (Author's abstract)

HEIN, U.F., LUDERS, V. and **DULSKI, P.**, 1989, The fluorite vein-mineralization of the southern Alps, Italy: Combined application of fluid inclusions and REE distribution (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 47. First author at FG Petrologie, Tech. Univ. Berlin, EB 310, Strd. d. 17, Juni 135, D-1000 Berlin 12, FRG.

The major South-Alpine fluorite veins are spatially connected with either late Variscan granitoids of the pre-Permian basement and/or acid Permian volcanites. They display a simple and uniform mineralogy comprising fluorite, quartz, local calcite and barite, and minor sulphides. Textures, such as syngenetic brecciation, rhythmic banding and crystal zoning are common. Previously, the genesis of these veins has been discussed with respect to Variscan magmatism, Permian volcanism, Permo-Triassic weathering, Triassic igneous activity, and the Alpine orogeny.

From numerous occurrences of vein fluorite mineralization, the deposits of Rabenstein/Corvara, Brantental/Vallarsa, and Prestavel in the Bozen area, Vignola near Trento, and Torgola in Val Trompia north of Brescia were chosen for a comparative study. Hydrothermal activity commonly starts with host-rock silicification and local potassic alteration. Post-crystalline deformation of varying intensity is a common feature of the veins. Thus, P FI are rare in the fluorites and may be observed as relics only. They contain aqueous solutions of medium to high salinity, frequently together with hydrocarbons and local variations of H_2S. At the Torgola mine, the P fluids have been completely quenched out. REE distribution patterns indicate mineralization by remobilization of either earlier fluorite precipitates or F and REE movement from the parent rocks, e.g., late Variscan granitoids or Permian rhyolitic to rhyodacitic ignimbrites. A north-south trend of increased REE-fractionation during mineralization is obvious for the deposits of the Bozen-Trento area. This trend indicates a homogenous fluid composition for the northern deposits (Rabenstein, Vallarsa) whereas the more southern deposits (Prestavel, Vignola) show a more complex history. The origin and mixing of different fluid systems during fluorite precipitation will be discussed in detail (Authors' abstract)

HEINRICH, C.A., ANDREW, A.S., WILKINS, R.W.T. and **PATTERSON, D.J.**, 1989, A fluid inclusion and stable isotope study of synmetamorphic copper ore formation at Mount Isa, Australia: Econ. Geol., v. 84, p. 529-550. First author at Bureau of Mineral Resources, Geology and Geophysics, Division of Petrology and Geochemistry, GPO Box 378, Canberra, ACT 2601, Australia.

Earlier structural studies indicate that the dolomitic and siliceous breccias and contained copper mineralization at Mount Isa (Queensland, Australia) formed during regional deformation and greenschist facies metamorphism of their host mid-Proterozoic metasediments. (...)

Fluid inclusions in quartz and dolomite were studied by microthermometry, micro-Raman spectrometry, and semiquantitative electron microprobe analysis of inclusion salts. Two types of aqueous inclusions are restricted to dolomitic breccia: $CaCl_2$-rich (group I) with a cation ratio Na/Ca/K/Mg $\simeq$ 30:10:3:1 and salinity (~25 wt %) similar to recent Salton Sea geothermal brines; and low-salinity with 10 to 20 mole % CO_2 (CO_2-rich, group 2). These two aqueous inclusion types are intimately associated in the same crystals and have probably both been trapped during dolomitic alteration.

Siliceous alteration superimposed on dolomitic breccia contains NaCl-rich fluid inclusions (group 3: Na/Ca/K/Mg $\simeq$ 300:10:30:1, minor CH_4). Microstructures suggest that earlier higher salinity (10-20 wt %) and later lower salinity (4-9 wt %) variants of this NaCl-rich fluid bracket the main stage of chalcopyrite introduction. There are no low-density vapor inclusions indicative of any stage of fluid boiling. Rare high-density $CH_4(\pm CO_2)$-rich carbonic inclusions are association with NaCl-rich aqueous inclusions in a few samples. S inclusions of a highly calcic low-T brine (group 4) occur along late healed cracks and postdate all major stage of mineral precipitation.

The C, O, and H isotope compositions of dolomite, quartz, and hydrous silicates and of fluid inclusion extracts from samples of the siliceous alteration zone were imposed by the externally derived, weakly $CH_4 + CO_2$-bearing, NaCl-rich fluid at high fluid/rock ratios and over a small range of T. This fluid may have originated as a highly evolved basin brine or an evaporite-derived metamorphic fluid. The early $CaCl_2$-rich fluid may have had an origin similar to the NaCl-rich ore fluid, but its different δD and the mass balance constraints arising from its chemical composition suggest that it has not been derived from the NaCl-rich fluid by progressive rock interaction within the zoned alteration system. Similarly, an independent source is likely for the CO_2-rich fluid.

The absolute P-T ranges for the two alteration processes seem to be slightly different, but it is uncertain whether the quartz-chalcopyrite mineralization occurred at slightly lower T or higher P compared with the dolomite alteration. The latter is confined to 270° to 350°C and 700 to 1,500 bars by isochore and mineral stability data.

The following working hypothesis for the syntectonic and synmetamorphic fluid-rock interaction and copper ore formation at Mount Isa is proposed. In an initial stage, dolomitic alteration occurred by chemical interaction between the Urquhart Shale and moderate amounts of two fluids of different chemical and hydrological origin, represented by the $CaCl_2$-rich and the CO_2-rich fluid inclusions. Fluid mixing may have been aided by extension on the limb of a regional fold which temporarily lowered fluid P, thus leading to hydraulic brecciation and fluid influx from two fluid regimes, above and below. The CO_2-rich fluid probably represents the local metamorphic fluid of the Urquhart Shale, whereas the $CaCl_2$-rich brine was introduced from the underlying altered greenstones. The initial stage of brecciation and dolomitic alteration was followed by the main stage of silicification and copper introduction by the much more copious NaCl-rich fluid, probably at near-lithostatic fluid P. Quartz and chalcopyrite precipitation occurred by a combination of slight cooling, a pH increase, and possible an increase in sulfur activity, as the initially reduced, acid, and possibly S-deficient, NaCl-rich fluids reacted with the previously dolomitized pyritic and dolomitic Urquhart Shale. (Authors' abstract)

HEINRICH, C.A. and **COUSENS, D.R.**, 1989, Semi-quantitative electron microprobe analysis of fluid inclusion salts from the Mount Isa copper deposit (Queensland, Australia): Geochim. Cosmochim. Acta, v. 53, p. 21-28. First author at CSIRO Div. Explor. Geosci., P.O. Box 136, North Ryde, NSW 2113, Australia.

Abundance ratios of major and minor elements in single FI from the synmetamorphic Cu deposit at Mount Isa (Queensland, Australia) have been estimated by electron microprobe analyses of salt residues liberated by thermal decrepitation. X-ray intensity ratios were calibrated using thin mixed-salt standards. Measured cation ratios are within ±20% of the values in the parent FI, provided that decrepitation can be achieved below 400°C. Wave-length dispersive spectrometry (WDS) used here is less accurate for major salt components, but more sensitive for minor elements, than energy dispersive spectrometry (EDS) used recently by Haynes and Kesler (1987).

Results demonstrate the advantage of the single-inclusion method for studying paragenetically complex ore samples containing several generations of inclusions. Microprobe analyses could be assigned to single FI or small groups of inclusions, which were texturally interpreted as P and S, and which were characterized by microthermometric measurements prior to decrepitation. In favorable cases, the combination of microthermometry and microprobe analysis allowed estimation of absolute cation concentrations in individual FI. Syntectonic metasomatism at Mount Isa involved highly calcic brines with major KCl and $AlCl_3$ in early dolomitic alteration preceding Cu mineralization. Compositionally similar fluids were again trapped on cracks postdating mineralization. The main stage of Cu mineralization was deposited by a NaCl-dominated brine with a composition of about 2 m (mol/kg) NaCl, 0.2 m KCl, 0.01 m each of S (as $HS^- + H_2S$) and $AlCl_3$, and with $MgCl_2$ and $FeCl_2$ near or below their respective detection limits of 0.002 and 0.01 m. (Authors' abstract)

HEINRICH, C.A. and **ETHERIDGE, M.A.**, 1989, Hydrology and water-rock reaction during regional metamorphic ore formation: Mount Isa example (Australia) (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-47.

HEINRICH, C.A. and **JAIRETH, S.**, 1989, Fluid buffering and wall rock interaction in the chemical evolution of granite-related tin-tungsten veins (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-47-48. Authors at Bureau of Mineral Resources Geology and Geophysics, Div. Petrology and Geochemistry, Canberra, Australia.

The majority of hydrothermal Sn and W deposits are hosted by veins and breccias associated with shallow, highly differentiated granitic intrusives. Fluid inclusion and isotopic evidence indicates that the ore fluids have equilibrated with magmatic source rocks at near-magmatic T and probably contain a major contribution of primary magmatic fluid. Ore deposition occurred at variable but generally lower T, in most deposits below 400°C and in some as low as 250°C. A trend of falling T during the paragenetic evolution of the veins is common, and evidence for boiling and/or mixing of hot saline fluids with cooler lower-salinity meteoric waters has been described. Wall rock alteration in quartzofeldspathic host rocks generally includes muscovite formation, which typically occurs within the veins and in selvages of completely "greisenized" wall rock. Spatially restricted alteration haloes indicate channelling of ore-depositing fluids into veins where they were isolated from mineral buffer assemblages of the country rock during parts of their chemical evolution. (From authors' abstract by E.R.)

HEINRITZI, F., WILLIAMS-JONES, A.E. and **WOOD, S.A.**, 1989, Fluid inclusions in calcite and dolomite of the REE-zone in the St. Honore carbonatite complex, Quebec (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-20. Authors at Dept. Geol. Sci., McGill Univ., Montreal, Quebec H3H 2A7, Canada.

The occurrence of FI (liquid-vapor, liquid-vapor-solid, the latter containing one or more dms) in the calcite and dolomite of the REE-zone of the St. Honore carbonatite is clear evidence of postmagmatic hydrothermal activity. We have identified two separate compositional trends: low T-low salinity and high T-high salinity. Liquid-vapor Th of both FI types are similar, ranging from 100°C to 320°C with a maximum between 190°C and 210°C, indicating a relatively low T of the hydrothermal system. Initial Tm ice between -21°C and -37°C indicate that the fluids contain other salts besides NaCl.

REE(Nd-Eu)-bearing solids occur as dms or trapped phases in some FI confirming the mobility of REE in aqueous solutions. This suggests, in turn, that the bastnaesite (the main REE-mineral in the REE-zone) may also be of hydrothermal origin. The fluids also contained a variety of elements besides the REE (Ca, Sr, Ba, Mg, Mn,K, Na, S), which is reflected in the abundance and composition of dms. The most common dms are strontianite ($SrCO_3$) and nahcolite ($NaHCO_3$). Nahcolite dissolves between 90°C and 130°C and in the process releases CO_2 which increase the vapor bubble diameter and commonly leads to decrepitation of the inclusion before homogenization. (Authors' abstract)

HELFFRICH, G.R. and **WOOD, B.J.**, 1989, High-pressure fluid P-V-T properties from fluid perturbation theory (abst.): Eos, v. 70, p. 486. Authors at Dept. Geol. Sci., Northwestern Univ., Evanston, IL 60208.

We have used several perturbation theories as a means of extending thermodynamic data into the mantle P-T regime.

A variety of fluids (CH_4, Ar, N_2, O_2, H_2, CO, CO_2, SO_2, H_2S and H_2O) of theoretical and geologic interest have been treated with this approach. When compared with available high-P experimental data, we find that P may be calculated, for a given V and T, to within ~6% for Ar (150 to 360 kb), ~7% for N_2 (200-370 kb), and RT1nf for CO_2 is approximately within experimental error up to 40 kb. The results indicate that perturbation theories will give better PVT data in the mantle P-T range than can be obtained from empirical or semi-empirical equations of state such as the Redlich-Kwong equation. (From authors' abstract by E.R.)

HEMLEY, R.J., CHEN, L.C. and **MAO, H.K.**, 1989, New transformations between crystalline and amorphous ice: Nature, v. 338, p. 638-640. Authors at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008, USA.

Studies mainly in the range 75-150°C and 1-6 GPa. (E.R.)

HERMS, P. and **SCHENK, V.**, 1988, Retrograde decomposition of cordierite under the influence of CO_2 in granulite-facies metapelites of southern Calabria (abst.): Fortsch. Mineral., v. 66, Beiheft 1, p. 56 (in German).

The stability of cordierite in the presence of water in low P and T is limited by the reaction cordierite + $H_2O \rightarrow$ chlorite + andalusite + quartz (Seifert and Schreyer, 1970). In the lower crust metapelites of Calabria, there occurs also a partial decomposition of cordierite to andalusite + magnesite + quartz under the influence of CO_2, limited by T < 530°C and P < 4 kbar. Indications of the fluid compositions present during the cordierite decomposition were obtained by analysis of the channel fluids of the cordierite, from the experiments of Johannes and Schreyer (1981), and from the composition of fluid inclusions in cordierite. From the XCO_2 value of the Calabrian cordierites of 0.6, there results the XCO_2 value of the coexisting fluids of 0.95. This is consistent with the fluid inclusion data, because H_2O in inclusions was not detected optically. Microthermometric studies and mass spectrometry data of the fluid inclusions indicate that the fluids contained mostly CO_2 plus subordinate amounts of CH_4 and N_2, the approximate ratio

$CO_2:CH_4:N_2 = 10:1:2$. The fluid inclusion density ranges from 0.78 to 0.87 g/cm^3 if a plot of pure CO_2 is applied. (From the authors' abstract shortened and translated by A.K.)

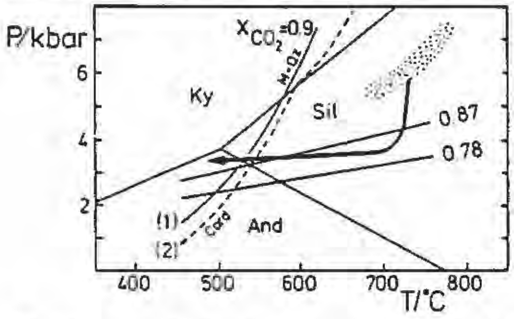


Figure 1. Retrograde P-T path of the Calabrian metapelites and the CO_2 isochores of fluid inclusions.

HERMS, P., SCHENK, V. and LE BRETON, N., 1989, Fluids in cordierite-bearing metapelites of the lower crust of the Serre, Calabria, Italy (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 48. First author at Mineral.-Petrogr. Inst., Univ. Kiel, Olshausenstrasse 40, 2300 Kiel 1, FRG.

Along the tilted cross section of the ancient lower crust of southern Calabria a sequence of granulite up to amphibolite-facies rocks are exposed. Towards the upper part of the section, an increase of retrograde hydration occurs. The aim of this research is to obtain information on the prograde and retrograde fluid composition. Cordierite-bearing samples proved especially suitable for estimating the fluid composition, as the composition of the rock fluid can be deduced from the fluid in the structural channels of the cordierite. The results of preliminary work are as follows: (i) No information concerning the composition of fluid at peak metamorphism composition can be obtained, as early inclusions of high density are missing. (ii) CO_2-rich FI of medium density (0.87-0.78 g/cm^3), without visible water content, probably indicate the rock fluid composition during uplift and isobaric cooling after peak metamorphism. During this stage, the cordierite channel fluid reequilibrated: the CO_2-content of ~1.9 wt % ($XCO_2 = 0.6$) in cordierite points, according to the experimentally determined distribution coefficient (Johannes, and Schreyer, 1981, Am. J. Sci., 281, 299), to $XCO_2 = 0.95$ for the rock fluid composition. This is in agreement with FI and optical (opt. +) data. XCO_2 in the rock fluid must still have been high during the retrograde decomposition of cordierite to andalusite + magnesite + quartz at $P < 4$ kbar and $T < 530$°C. (iii) At still lower T conditions during the pinitization of the cordierite the fluid must have changed to a more H_2O-rich composition. Pinitized cordierites are optically negative near the pinite veins, while the core of the cordierite is still optically positive. This trend to a late, more H_2O-rich composition of the fluid in the cordierite agrees with late FI found in quartz. (iv) The CO_2/H_2O ratio and total fluid content of cordierites from the whole lower crustal section does not vary systematically from sample to sample. This indicates local fluctuations of the fluid composition after the metamorphism of the rocks. (Authors' abstract)

HERRINGTON, R.J., 1989, Fluid inclusions as indicators of fluid chemical evolution in a shear hosted gold mineralized system at Patchway Mine, Zimbabwe (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 49. Author at Dept. Geol., Imperial College, London, UK.

Mineralization at Patchway is hosted within a thin, classic resurgent brittle-plastic shear zone. This is wholly developed within the ca. 2.7 Upper Mafic formation of the Upper Bulawayan Group in the Chegutu-Kadoma greenstone belt. Regionally this is the most important stratigraphic unit for Au production. The Patchway shear zone and other subparallel zones transect a sequence dominated by Fe-rich tholeiitic lavas.

Early deformation expressed by upright F1 folding further developed in a period of dextral strike slip shearing accompanied by tonalite-trondhjeimite intrusion into the shear system. Fluid-facilitated shearing then resulted in alteration through wall rock interaction, and this evolved to dominantly crack-seal quartz precipitation accompanied by sulphide and Au mineralization. The system then evolved to an apparently fluid-poor regime and further strike-slip resulted in boudinage and termination of mineralization. A later period of deformation resulted in dip-slip normal reactivation of the shear zone accompanied by precipitation of quartz tourmaline mineralization and local remobilization of sulphides.

Strong relationships between the development of the shear zone and the tonalite diapirism expressed as the Lion Hill and Whitewaters stocks is evident, particularly in regard to the latest deformation/mineralization event.

FI studies suggest at least two fluid types present during the life of the shear zone. The earlier fluid is a high T (350-400°C) low salinity (2-4 wt. % NaCl eq.) CO_2-rich fluid which contains other miscible gases such as

CH_4 and N_2. There is also evidence for phase separation in this fluid, with coexisting two-phase CO_2-poor inclusions and three-phase CO_2-rich inclusions of variable degrees of fill. The later fluid is of distinctly different chemistry, being low T (180-200°C) high salinity (15-20 wt. % NaCl eq.) and containing low levels of miscible gas. Thermometric and chemical data indicate the presence of cations such as B, Ba, Rb, Sr as well as high Ca, Mg, K levels which indicate a fundamentally different source. The early fluid phase can be genetically linked to the Au-bearing quartz-sulphide mineralization whilst the later fluid was responsible for late quartz-tourmaline mineralization. (Author's abstract)

HERRINGTON, R.J. and **SHEPHERD, T.J.**, 1989, Detailed fluid inclusion studies of ribbon quartz veins at Patchway gold mine, Zimbabwe (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 59. First author at Imperial College.

Gold-pyrite-scheelite-quartz veins of Archaean age at Patchway mine show distinct ribbon textures, typical of many similar brittle-ductile shear hosted deposits. Ribbon textures are interpreted as forming as the result of multiple episodic crack-seal and mineral precipitation, which in the case of Patchway occurred during shearing and probable fluid-induced brittle dilation of the shear structure.

Au transportation and precipitation mechanisms in such Au deposits are still the subject of much discussion, but Au is most likely to be transported in a bisulphide complex. During the successive crack-seal events Au, pyrite, scheelite, carbonate and quartz co-precipitate, and detailed fluid evolution at this time must reflect these events.

Destabilisation of the bisulphide complex to precipitate Au in such a regime is probably best effected by phase separation with volatilisation of H_2S into a vapour phase (together with other volatiles of high partition coefficients). The H_2S is probably fixed mainly as pyrite and the remaining fluid then becomes H_2O-CO_2 dominated and more oxidised. Phase separation can be induced by a number of events including catastrophic P release through brittle failure or "salting out" phenomena by mixing with a more saline fluid or addition of volatiles such as CH_4 to the fluid.

At Patchway microthermometric and volatile analysis of P fluid inclusions populations in the Au-bearing veins shows the ore fluid to have been a low salinity carbonic and partly methanoic fluid which shows some degree of systematic chemical variation between different quartz "ribbons."

The presence of CH_4 in inclusions associated with Au-rich portions of the veins can be demonstrated and the presence of CH_4-poor inclusions in "barren" sections may be indicative of CH_4 loss from the fluid after the phase separation/Au precipitation event together with its other concomitant reactions. (Authors' abstract)

HERVIG, R.L. and **DUNBAR, N.W.**, 1989, Direct determinations of volatile gradients in the Bandelier Tuff through analysis of melt inclusions (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 129. First author at Center for Solid State Science, Arizona State Univ., Tempe, AZ 85287-1704.

The Lower Bandelier Tuff and precursor plinian tephra, which erupted at 1.45 Ma in northwestern New Mexico, are thought to be the product of a zoned magma chamber. We have attempted to directly determine the pre-eruptive volatile gradient of this magmatic system using ion and electron microprobe analyses of melt inclusions in magmatic phenocrysts. Large melt inclusions ($\leq$400 microns in diameter) are abundant in quartz crystals from the Lower Bandelier ignimbrite and associated plinian tephra. Melt inclusions in phenocrysts from the plinian tephra are generally composed of clear glass and contain few shrinkage bubbles. Most inclusions appear to be P, but some fill pockets where the host crystal had been resorbed or had incompletely grown. Inclusions in crystals from the ignimbrite samples generally contain shrinkage bubbles, and the size and number of bubbles varies between inclusions. some inclusions appear altered, but pristine inclusions can be found.

Major element composition of pristine melt inclusions closely resembles bulk rock composition, which suggests that no extensive post-entrapment crystallization has taken place, and no zone of compositionally altered melt developed around the growing crystal. In cases where inclusions appeared altered, patchy remobilization of K and Na can be detected by electron microprobe analysis. Some pocket-filling inclusions from the plinian tephra appear pristine but have a uniformly high K_2O content and correspondingly low Na_2O. This does not appear to be due to alteration and may represent a localized high-K zone in the upper portion of the magma chamber.

Mean H_2O contents of melt inclusions from two bulk pumice samples from the Lower Bandelier plinian tephra are 4.7 wt % (n = 4, base of plinian) and 4.3 wt % (n = 10, top of plinian). Melt inclusions from a bulk sample of the transition zone between the plinian tephra and the Lower Bandelier ignimbrite have a mean H_2O content of

4.3 wt % (n = 12), and melt inclusions from three samples of the Lower Bandelier ignimbrite contain 1.7, 2.1, and 2.2 wt % H_2O (n = 14, 21, and 14, respectively). The three samples of the ignimbrite are from different stratigraphic heights, but due to the eruptive style of the ignimbrite, these cannot be directly correlated to the original depth in the chamber. Trace element chemistry determinations by neutron activation analyses of bulk samples (one pumice lump each) will allow determination of the relative positions of ignimbrite samples. Other analysed elements which are known to be compatible in a magmatic volatile phase include F, Cl, B and P. The mean contents from melt inclusions in the two plinian samples and the transition sample are: F 0.22, 0.24 and 0.14 wt %; Cl 0.24, 0.29 and 0.20 wt %, B 47, 46 and 41 ppm; and P 186, 283 and 154 ppm (n = 4, 10 and 12, respectively, for F, B and P; n = 6, 18 and 19 for Cl). The mean contents of the ignimbrite melt inclusions, in the order given above, are: F 0.08, 0.14 and 0.07 wt %; Cl 0.17, 0.21 and 0.16 wt %; B 26, 28 and 18 ppm; and P 174, 183 and 170 ppm (n = 14, 21 and 14, respectively, for F, B and P; n = 23, 28 and 26 for Cl). These data suggest that a volatile gradient was present in the magma which produced the Lower Bandelier plinian and ignimbrite, and that the degree of gradient present varied between elements. The highest H_2O content observed in a plinian inclusion was ~5 wt %, and the lowest in an ignimbrite inclusion was ~1.0 wt %, which define the range of the H_2O gradient with the data we now have available. The calculated density contrast between a Bandelier melt with 1 and 5 wt % H_2O is ~0.16 g/cm^3.

Certain trace elements were also analysed by ion microprobe in Bandelier melt inclusions. The trace elements in the large set of inclusions cover the approximate range of trace elements seen in the Lower Bandelier plinian and ignimbrite and show a rough inverse correlation with the volatile contents of the inclusions. (Authors' abstract)

HERVIG, R.L., DUNBAR, Nelia, WESTRICH, H.R. and KYLE, P.R., 1989, Pre-eruptive water content of rhyolitic magmas, as determined by ion microprobe analyses of melt inclusions in phenocrysts: J. Volcanol. Geotherm. Res., v. 36, p. 293-302. First author at Dept. Chemistry, Arizona State Univ., Tempe, AZ 85287.

The ion microprobe was used to analyze trapped melt inclusions in phenocrysts from two rhyolitic eruptions for H_2O, F and incompatible trace elements. Eleven melt inclusions from phenocrysts in air-fall tephra from Obsidian Dome near Long Valley, USA gave an average of 4.1 ± 1.2 wt % H_2O and showed large variations in F and incompatible trace elements reflecting a complex history reported to involve mixing of at least two magma types. Eight inclusions in phenocrysts from the Taupo "ultraplinian" event, New Zealand gave 4.5 ± 0.8 wt % H_2O with small variations in the other elements analyzed. Measured water contents are similar to earlier estimates of the pre-eruptive water contents of these and similar rhyolites and major- and trace-element analyses of inclusions compare closely with bulk analyses suggesting that the analyses of inclusions represent the chemistry of the magma at the time of entrapment. (Authors' abstract)

HERZIG, P.M., SCHÖPS, D., FRIEDRICH, G.H. and SCOTT, S.D., 1989, Quartz-sulfide veins in the sheeted dike section of ODP Hole 504B: Implications for fluid characteristics in the Lower Oceanic Crust (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-54. First author at Institut für Mineralogie und Lagerstättenlehre, Aachen, F.R.G. and Marine Geology Research Group, Dept. Geology, Univ. Toronto, Toronto, Ontario, Canada.

Fluid inclusions in quartz from the quartz-sulfide veins are two-phase and vary from liquid- to vapor-dominated. Their salinities range from 4.2-7.2 wt % eq. NaCl and average 5.5 wt %. P corrected (360 bars) average Th for four vein quartz samples vary from 271 to 408°C; maximum Th are between 345 and 486°C (n = 117). Oxygen isotope thermometry on a single vein quartz separate ($\delta^{18}O$ + 4.2‰) yields a range of possible formation T from 390 to 510°C, assuming equilibrium with a fluid $\delta^{18}O$ value of 0 to +2‰. These data indicate alteration of the lower sheeted dikes at T of 400 ± 50°C. The maximum fluid inclusion Th intersect the liquid/vapor two-phase boundary above the critical point of seawater. Thus, phase separation could have occurred locally during the formation of the mineralized veins and the alteration of the sheeted dike complex.

The high Co concentrations observed in the vein sulfides from the leg 111 sheeted dikes suggest that deeply circulating, moderately saline, high T fluids carry significant amounts of Co in solution. The range of fluid inclusion T and salinities as well as the variations in sulfide chemistry are interpreted to be a result of multiple stages of hydrothermal activity involving fluids of different T and composition. Changes in the physico-chemical fluid parameters are obviously related to the location of the crust during spreading, i.e., to axis and near-axis hydrothermal regimes. (From authors' abstract by E.R.)

HESLOT, F., FRAYSSE, N. and CAZABAT, A.M., 1989, Molecular layering in the spreading of wetting liquid drops: Nature, v. 338, p. 640-642. Authors at Col. France, Phys. de la matière condensée, 11 place Marcellin-Berthelot, 75231 Paris Cedex 05, France.

An experimental study of wetting phenomena of pertinence to liquid/solid wetting in FI. See also Ball, this volume. (E.R.)

HESS, P.C. and RUTHERFORD, M.J., 1989, Crystal fractionation, immiscibility and granite (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A301. Authors at Dept. Geological Sciences, Brown Univ., Providence, RI 02912.

To the surprise of many petrologists, petrographic and experimental data prove that low P crystal fractionation of lunar basalts produces granites by silicate liquid immiscibility. The two-liquid solvus is the analog to that in the leucite-fayalite-silica system, but is wider because solidus T have been lowered to <975°C, and the solvus expanded by the addition of TiO_2 and P_2O_5. The liquid lines of descent of lunar basalts are obtained at low $f(O_2)$ and essentially zero $f(H_2O)$ and intercept the solvus at SiO_2 contents of 48-56%, at 1050 to 990°C and with 10 to 30% liquid remaining. Granites and ferrobasalts are produced by andesites and dacites are not. Previous experiments and those now in progress indicate that increasing P enhances immiscibility and, therefore, immiscible granites could exist throughout the lunar crust.

What about the terrestrial experience? Low P liquid lines of descent of terrestrial basalts obtained under virtually anhydrous conditions also produce granites by immiscibility. Immiscible granite glasses are ubiquitous in the mesostasis of tholeiite and even some alkali basalts. Anhydrous crystallization experiments of tholeiite basalt invariably produce immiscible granites by exsolution from ferrobasalts. Experiments done on hydrous basalts, however, produce andesites, dacites and then granite. No silicate liquid immiscibility exists. Natural melts produced in the Kilauea Iki lava lake show a complete gradation from basalt to granite, a consequence of oxidizing conditions and modest $f(H_2O)$. Thus, even small amounts of H_2O in the parent basalt may preclude silicate liquid immiscibility in the evolved residual liquids. The $f(H_2O)$ that eliminates the two liquid fields, however, has not been established.

The lunar studies have elevated silicate liquid immiscibility from a scientific curiosity to one that can be understood and predicted, and have shown that there are granites and there are granites! (Authors' abstract)

HESSE, R. and DALTON, E., 1989, Thermal maturation of Paleozoic shales, Gaspe Peninsula, Quebec Appalachians (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-77. Authors at Dept. Geol. Sci., McGill Univ., Montreal, Quebec H3A 2A7, Canada.

An illite crystallinity map for Gaspe-Peninsula, a 27,000 km^2 large area, reveals general congruence between crystallinity contours (based on 2,200 sample points) an structural trends. The tectonic contact between the Taconic and Acadian belts is marked by a first order discontinuity in the maturation pattern. Tectonic displacements along postulated major strike-slip faults in the Acadian belt (Bourque et al., 1985, 1986) do not find expression in the map. In the Taconic belt, a wide high-grade (anchimetamorphic) aureole around the Devonian McGerrigle Mountains pluton dissects the generally E-W trending maturation zones which display northward (cratonward) decreasing grades west of the pluton and northward increasing grades east of it. In the Acadian belt, the highest grades (anchimetamorphism) are associated with the oldest rocks (Honorat and Matapedia Groups, parts of the Chaleurs Bay Group) exposed in the center of major anticlines reflecting principally a burial-diagenetic trend. High grades associated with the Lower Devonian Fortin Group, particularly its western outcrop belt, require considerable subsidence to accommodate 7-8 km of younger sediments (Gaspe Sandstone etc.) on top of 4 (-5) km Fortin Group deep-water clastics. Relatively low maturation levels characterize Siluro-Devonian rocks of the northeastern and northwestern parts of the Acadian belt, as well as the Ordovician Mictaw-Group. Interpretations of the maturation patterns based on illite crystallinity are augmented by organic matter reflectance data, percent 2M mica polymorphs, estimates of mica and chlorite (XRD-) compositions and, for the Taconic belt, FI thermometry. (Authors' abstract)

HEUSSER, E., KIRSTEN, T., SCHÄFER, K., RICHTER, H. and **OEHM, J.**, 1989, Mass spectrometric analysis of noble gas isotopes (abst.): Max-Planck Inst. für Kernphysik Heidelberg, Jahresbericht, 1989, p. 161 (in German, English abstract).

We continued our efforts to measure all stable rare gas isotopes in rocks from the core of the Continental Deep Drilling. The most important new result is the identification of mantle-derived helium. (Authors' abstract)

HILTON, D.R. and **CRAIG, H.**, 1989a, Helium isotopes and gas chemistry of volcanic arcs: A transect along the Sunda Arc of Indonesia (abst.): Eos, v. 70, p. 1388.

HILTON, D.R. and **CRAIG, H.**, 1989b, A helium isotope transect along the Indonesian archipelago: Nature, v. 342, p. 906-908.

HILTON, D.R. and **CRAIG, H.**, 1989c, The Siljan Deep Well: Helium isotope results: Geochim. Cosmochim. Acta, v. 53, p. 3311-3316. First author at Free Univ. Berlin, FB 24, WE 1 FR Geochemie, 1000 Berlin, West Germany.

No evidence of a mantle helium component is observed in the isotopic data: an upper-limit calculation based on the difference between He isotope ratios in the granite and in the formation waters gives a maximum of 0.15% of MORB helium in the well gas helium. (From authors' abstract by E.R.)

HOATSON, D.M. and **KEAYS, R.R.**, 1989, Formation of platiniferous sulfide horizons by crystal fractionation and magma mixing in the Munni Munni layered intrusion, west Pilbara block, Western Australia: Econ. Geol., v. 84, p. 1775-1804. First author at Bureau of Mineral Resources, P.O. Box 378, Canberra, ACT 2601, Australia, and Dept. Geology, Univ. Melbourne, Victoria 3052, Australia.

The chalcophile platinum-group elements, due to their high sulfide/silicate partition coefficients, were scavenged by immiscible sulfide droplets which precipitated slowly in a porphyritic plagioclase websterite in a zone up to 20 m below the ultramafic-gabbroic zone contact. (From authors' abstract by E.R.)

HOEFS, Jochen, 1989, On the origin and interaction of fluids in the continental and oceanic crust: Niedersächsische Akademie der Geowissenschaften, Publication Heft 1, Gesteinsfluide, p. 43-48. Author at Geochem. Inst. der Univ. Göttingen, Goldschmidtstr. 1, D-3400 Göttingen, FRG.

A short review of the use of O and H isotope determinations to understand fluid/rock interactions. (E.R.)

HOEGELSBERGER, H., 1989, Fluid inclusions in polymetamorphosed rocks of the Bohemian Massif, Austria (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 50. Author at Dept. Geol., University College, Galway, Ireland.

Two metamorphic events may be deduced in the Moldanubian Varied Group in Lower Austria. The first took place at P-T conditions of ~700°C and 7 kb and is probably of Caledonian age. The second event reached 500°C. This retrograde overprinting was caused by the Hercynian subduction of the Moravian under the Moldanubian Unit. Aqueous FI were studied in quartz and scapolite from marbles and calc-silicate rocks. The polymetamorphic history is documented by the bimodal distribution of their Th.

The inclusions of the first event are P, they are up to 100 μm long and have a high Th. Mostly they have Th L (Th: 260-360°C). In two samples the inclusion have Th V (Th: 420-470°C). In this case the resulting isochores are very flat in the P-T field. This indicates for the known peak T much too low a value for Pfluid. Hence these two samples are examples of the condition Pfluid < Ptotal and indicate boiling of the fluid phase.

The inclusions created by the retrograde metamorphism and the subsequent cooling are clearly S and smaller (up to 10 μm). They homogenize without exception to liquid (Th: 120-250°C). (Author's abstract)

HOERNES, S. and **RAITH, M.,** 1988, Origin, mobilization and precipitation of carbon in granulite-facies rock series of southern India (abst.): Fortsch. Mineral., v. 66, part 1, p. 65 (in German).

Charnockites of the biotite-garnet gneiss series (Khondaite belt in Kerala, 550 Ma) formed at 700-750°C, 5-6 kbar, in the presence of a CO_2-dominated fluid phase. The value of $\delta^{13}C$ of graphite (-17 to -14‰) indicates isotopic equilibrium with CO_2 of fluid inclusions (-7 to -17‰). (From the authors' abstract translated by A.K.)

HOFFER, E., SCHMIDT, F. and **SCHÜRMANN, K.U.,** 1989, Experimental studies of assimilation of metasediments by granitic melt (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 76 (in German) (supplementary issue to European J. Mineral., v. 1.).

The studies were performed on Qz-Ab-Or-H_2O melts and prepared from gels and amphibolite and gneiss "xenoliths" at $750 < T < 800$°C, PH_2O 2000-2600 bar, run duration seven days. No mineralogical changes were found in amphibolite, but an initial melting was found in gneiss at the grain borders between quartz + feldspar, and between quartz + biotite. (A.K.)

HOFMAN, Wladyslaw, 1989, The mass increment of quartz single crystal during hydrothermal process (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-42. Author at Inst. Tech. of Electronic Materials, 01-919 Warsaw, Poland.

The method of marking which makes it possible to evaluate the growth rate and the mass increment of quartz single crystal is presented. The marking method was applied to processes carried out in a large volume autoclave at the T-P conditions similar to those used in production runs. At certain time intervals the microinclusion bands, which marked the current crystallization front, were generated in crystals. Using this method the experimental record of crystal width versus time of growth was obtained $z_i(t_i)$. The empirical formula $z = at^b$ was fitted to $z_i(t_i)$ points/a,b - constant/. The rates computed as v_z - dz/dt showed that value of v_z decreases more than twice between the beginning and the termination of the process. With the help of v_z the "velocity" of mass deposition σm was estimated. To this end, the habit of synthetic crystal was replaced with geometrically simplified model. For this model the relation between σm and v_z can be formulated by equation $\sigma m = \sigma \bullet v_z \bullet S_{ef}$ where σ is αSiO_2 density and S_{ef} represents a measure of actual crystal growth surface. The S_{ef} increase, of the examined quartz bars, is significantly faster than the v_z decrease. As a result the value of σm increases about twice during the time of the process. It seems probable that the factors which control the convection of solution play the major part in the above increment, that is the concentrated flow and the gradients of radial T in the hydrothermal solution. (Author's abstract)

HOFMANN, B.A., 1989, Genesis, alteration and recent groundwater-flowsystem of the uranium deposit Krunkelbach (Menzenschwand, Black Forest): NAGRA Technischer Bericht 88-30, CH-Baden 1989 (195 pp. with 47 pp. appendix) (in German, English abst.).

The Krunkelbach U deposit consists of several steeply dipping veins dominated by quartz, hematite, barite, fluorite, pitchblende and Fe-Cu sulfides. The mineralization is of Upper Carboniferous age and is hosted by the Carboniferous Bärhalde granite. The history of water-rock interactions in this deposits was elucidated by means of mineralogical, geochemical and fluid inclusion studies and compared with radiometric ages obtained by other authors and during this study.

From the mineralogical and petrographic study of the veins, three stages of mineral formation and alteration can be defined. The earliest and main stage of mineral deposition is responsible for the formation of the quartz-rich veins including all the U- and Cu-mineralization. Feldspars in the granitic host rocks were altered to illite and partly to cookeite. The second vein stage is characterized by massive barite-fluorite-calcite veins. The third main stage of the deposit is mainly an oxidation event affecting and overprinting the earlier stages. Uranyl minerals, halloysite, smectite, barite and internal sediments in vugs consisting of gorceixite and fine quartz debris are the main minerals of this stage.

Fluid inclusions were studied microthermometrically in minerals of all three stages and in rock-forming quartz. Most fluid inclusions are found along healed cracks and therefore are of S origin. Three types of fluid inclusions were found: (I) two-phase inclusions with Th varying from 100 to 350°C, Tm -5 to 0°C; (II) two-phase inclusions with a maximum Th of 110 to 160°C; and (III) two-phase inclusions of very low salinity (Tm = 0.0°C). Due to variable vapor/water ratios, no significant Th could be obtained for these samples.

Type I inclusions were found mainly in rock-forming quartz and in stage I quartz; they are correlated with the formation of the ore deposit. They are missing in barite and fluorite of stage II. Type II inclusions occur in stage I quartz (always S) and are the only inclusions in stage II barite and fluorite. Type III inclusions were found in S barite only. These fluid inclusions are related to the oxidation event that occurred at least 300,000 years ago (^{230}Th-^{234}U age of secondary U minerals). The inclusions of types I and II were formed during two separate hydrothermal events, the first related to the formation of the deposit in the upper Carboniferous, the second probably related to a hydrothermal overprint of the deposit during the Tertiary. Further evidence for a two-stage hydrothermal history of the deposit is derived from stable isotopic differences observed in barite, quartz and hematite. (Author's abstract)

HOLLAND, H.D., 1989, Volcanic gases and isotopic record of carbon and sulfur in sedimentary rocks (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-66.

HOLLAND, P.T., BEATY, D.W. and SNOW, G.G., 1989, Comparative elemental and oxygen isotope geochemistry of jasperoid in the northern Great Basin: Evidence for distinctive fluid evolution in gold-producing hydrothermal systems—A reply: Econ. Geol., v. 84, p. 1707-1712.

See Jones and Leveille, 1989, this volume. (E.R.)

HOLLISTER, L.S., 1989, Enrichment of CO_2 in fluid inclusions in quartz by removal of H_2O during crystal plastic deformation (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A357. Author at Dept. Geological and Geophysical Sciences, Princeton Univ., Princeton, NJ 08544.

Ductile strain induced leakage of H_2O from mixed CO_2 + H_2O fluid inclusions is proposed as a mechanism for producing occurrences of pure CO_2 fluid inclusions in metamorphic rocks. It is argued that, during strain, stress will be concentrated at fluid inclusions. Due to the stress concentration, dislocations will nucleate on the inclusion walls. Crystal plastic flow of the quartz will occur due to dislocation creep facilitated by hydrolytic weakening provided by H_2O from the inclusion. The process should continue so long as there is stress on the inclusion and the inclusion contains H_2O. If the H_2O is totally drained during the crystal plastic flow, then a residual inclusion bearing components other than water should remain. A mixed CO_2 + H_2O inclusion would, as a consequence of the process, become a pure CO_2 fluid inclusion. Kerrick (1976) proposed a similar mechanism for explaining the absence of aqueous fluid inclusions in dynamically recrystallized quartz. The strain induced leakage of H_2O as a means of producing pure CO_2 fluid inclusions should be added to other mechanisms proposed for generating pure CO_2 fluid inclusions. If the proposed mechanism can be confirmed, then densities of CO_2-rich fluid inclusions could be used to determine P-T conditions of strain. (Author's abstract)

HOLMGREN, C., MART, M., SKEWES, A.S., SCHNEIDER, A. and HARMON, R., 1988, Isotopic analysis of fluid inclusions in the Los Bronces Deposit, central Chile (abst): Communicaciones, Una Revista de Geologia Andina (Communications, a Review of Andean Geology), 5th Geological Congress of Chile, Spec. Issue No. 39, p. 60 (in Spanish, translated by G. Landis).

We have studied the mineralization associated with both the early hydrothermal and open hydrothermal stages in the Los Bronces deposit, which forms part of the Cu porphyry mega-deposit, Los Bronces-Rio Blanco, which hosts important development of hydrothermal tourmaline breccias bearing Cu and Mo minerals, situated in the Alta Cordillera of Central Chile.

Thermometric data derived from studies of fluid inclusions in quartz suggest that the matrix of the breccias was formed in part by two distinct fluids: (1) of high salinity (34 to 56 eq. wt % NaCl), saturated, boiling, with T > 245°C, in cases exceeding 600°C, of probable magmatic origin; and (2) of undersaturated fluids, with variable salinity (3.8 to 17 eq. wt % NaCl), with Th between 235° and 467°C, with no evidence of boiling. This last [fluid], in all probability, represents a mixture between meteoric waters and magmatic fluids.

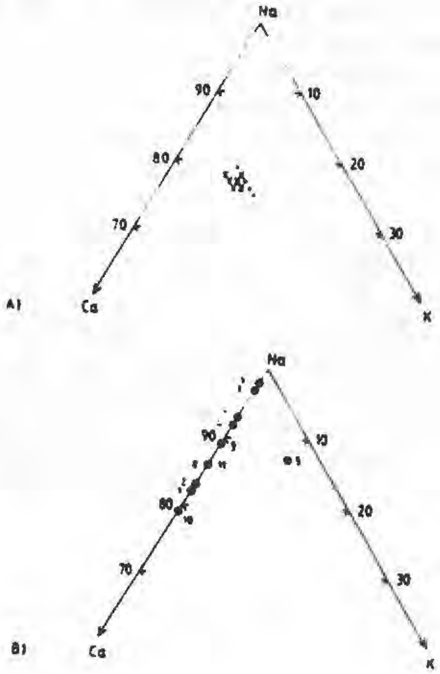
The quartz monzonite intrusive rock has fluid inclusions with saturated salinities (42 to 49 eq. wt % NaCl), with evidence of boiling at T between 308° and 358°C, and of magmatic origin. Quartz-molybdenite veinlets are superimposed on the quartz monzonite, and demonstrate lower salinities and Th between 290° and 380°C.

The sulfur [isotopes] of pyrite and chalcopyrite of distinct stages show $\delta^{34}S$ values between -0.5 and -4.8‰, with variations between equilibrium pairs that suggest Tf on the order of 650°C. O and H isotopes clearly define [discriminate well] the magmatic and metamorphic waters and demonstrate the important influence on mineralization [contribution to mineralization] of the final fluid. Fluid P determined in part from thermometric data suggest a depth of formation between 600 and 1300 m below the surface. (Authors' abstract)

HOMANN, K.D., 1989, Routine fluid inclusion investigations on borehole samples in the KTB Field Laboratory using an ICP-decrepitation technique (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 51-52. Author at KTB Field Lab., Oberpfalz, Germany.

In the KTB Field Laboratory near the drilling site of the German Continental Deep Drilling Project in the Oberpflaz, a geochemistry research group is working on FI study. During the first drilling campaign, which will be fully cored down to 5000 m (Sept. 87 - May 89) a suitable analytical technique had to be tested for routine use in FI analysis. Microthermometric measurements on the one hand, allow a first estimate to be made of temperature (Th), salinity (Tm) and composition (Te) of the trapped fluids. These kinds of investigations are, on the other hand, very time consuming, both in terms of preparation of polished thin sections and for the measurement itself. [For composition] only the D-ICP method is relatively easy and rapid. Only 500 mg of mineral separates are needed, [it] is a very sensitive method, and the possibility of contamination of the decrepitates by solid particles is rather low. The KTB Field Laboratory is equipped with an ICP-AES (ARL, 3580 vac.) capable of simultaneous measurements of Na, Ca, K, Li, Zn, P, S, Si, Al and Sc.

Figure 1 shows the results of the first D-ICP analysis performed on [quartz from] borehole samples. (A) Cation ratios of FI of a quartz sample ('Ekergneis,' Harz Mountains): x = D-ICP Imperial College, • = D-ICP KTB Field Lab. (B) Cation ratios of FI in quartz vein samples from [various depths to 2483 m in] the Continental Deep Drilling site, Oberpflaz, Germany. (Abbreviated by E.R. from the author's abstract)



HORN, E.E., McELDUFF, B., REUTEL, C. and STUMPFL, E.F., 1989, Fluid inclusions in chromites from the Troodos ophiolite, Cyprus (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-72. Authors at Institut fur Geologie und Dynamik der Lithosphäre der Georg-August Universität, Göttingen, Federal Republic of Germany.

A multitude of fluid inclusions of different generations has been identified in chromites from deposits within the ultramafic sequence of the Troodos ophiolite. The systematic documentation of these palaeofluids should contribute to an understanding of chromite genesis. In particular, this may indicate whether the chromites are of early magmatic origin or formed by the activity of late magmatic fluids. Since the chromitite bodies are always surrounded by a dunite envelope which may be metasomatic in origin, the possibility of a non-magmatic genesis shall also be considered. Microthermometry and other analytical techniques (Raman-microprobe, FT-IR, microprobe, SEM + EDX) have been employed during the course of research.

The occurrence of fluid and solid inclusions in chromites is well known and has been repeatedly observed and described (Whittaker and Watkinson, 1982; Johan et al., 1982; Johan, 1984; Talkington, 1986). However, due to the relative opacity of chromite, little thermometric data exist and few analyses of single inclusions have been made, which might be used for comparison. Research to date has shown that most chromite from the Cyprus ophiolite can be made transparent, at least IR-transparent, so that accurate measurements are possible.

Initial microthermometric and Raman-microprobe investigations of two-phase aqueous inclusions have been made. Of particular interest is the occurrence of H_2-bearing aqueous inclusions. The presence of H_2 in ultramafic rocks was first described by Helke (1961) from a borehole. H_2, together with other gaseous components, has been frequently detected in inclusions from various environments, especially in composite analyses by means of gas chromatography and mass spectrometry. H_2 in single inclusions has very rarely been observed, e.g., by Pagel et al. in the environs of a natural reactor. They attribute the presence of H_2 in inclusions to radiolysis in the presence of organic material. This possibility can be justifiably excluded from consideration in the case of chromite.

With respect to the chromite inclusions in question, the H_2 should be considered as an indicator of a strongly reducing milieu during chromite formation. Similar reducing conditions were deduced by Johan (1984) from the occurrence of methane in aqueous inclusions in chromite, detected by Raman spectroscopy. (Authors' abstract)

HORN, E.E. and TYE, C.T., 1989, Analysis of fluid inclusions in minerals by VG laser ablation ICP-MS (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 32. First author at Inst. Geol. and Dynamik der Lithosph re der Georg-August-Univ., D-3400 G@ttingen, Goldschmidt str. 3, FRG.

Only a few methods are available for analyzing single FI chemically. In this study it was therefore tested to what extent inclusion contents can be determined with ICP-MS by using a 500 mJ ND:YAG laser in fixed Q pulse mode. Detection limits for this technique are between 30 and 180 ng/g* for full range mass scans typically accumulated in sixty to ninety seconds. Investigations were carried out on quartz and fluorite.

The inclusions were opened by the laser device. The evaporated host mineral and the inclusion content were transported by argon as carrier gas into the ICP of a VG PlamaQuad ICP-MS for subsequent analysis.

Repeatedly, Li, Na, Mg, Ca, Rb, Sr, Al, Cu, Fe, Mn, Zn and As as well as Cl and Br were proven to occur in minerals. In crystal areas where only the host mineral was microscopically visible, the concentration of the elements given decreases clearly. In the inclusion area enriched isotopes and elements were also visible as they are connected with Cl enrichments. Inclusions with extremely low Te values are associated with significantly higher levels of Li, as might be expected; in addition, increased Ca and Mg values were detected in these regions.

In addition to survey analyses including the entire mass spectrum, inclusions which are known to contain Sr were measured. In the process the Rb and Sr contents were clearly proven in the inclusions. Comparison with host mineral or zones extremely poor in inclusions showed very low levels of the two elements.

These investigations indicate that LA-ICP-MS can be used to determine elements in FI minerals qualitatively. Under slightly altered conditions at least semi-qualitative results should be obtained. (Authors' abstract)

*Typo. in original.

HÖLL, Rudolf and SCHENK, Peter, 1989, Oldest preserved features of the Felbertal scheelite deposit (abst.): Terra Abstracts, v. 1, p. 34-35. Authors at Inst. Allgemeine and Angewandte Geol., Luisenstrasse 37, D-8000 München 2.

The scheelite deposit Felbertal is located in the central Hohe Tauern/Austria. We conclude, that the scheelite mineralization has formed during diagenesis from W-bearing precipitates. From FI studies on scheelite, quartz, beryl, fluorspar, and calcite it is obvious that the fluid content of these minerals is of Alpine origin. (From authors' abstract by E.R.)

HU, Hengming, 1989, Geology and origin of the Qiqiu No. 1 gold deposit, western Zhungeer, Xinjiang: J. Changchun Univ. Earth Sci., v. 19, no. 1, p. 53-62 (in Chinese; English abstract).

The Qiqiu No. 1 Au deposit belongs to quartz vein type and the auriferous quartz veins fill in the secondary fractures in the hanging wall of Anqi Fault. The country rocks of the ore bodies mainly consist of basalt. Native Au, arsenopyrite and pyrite are the main ore minerals of a content of 3~5% in average and often below 1%. The native Au usually fills in the cracks of the quartz veins. Au/Ag ratio of ores ranges from 2.70 to 35.42. The Th of the FI in the Au-bearing vein quartz ranges from 320°C to 160°C, largely from 270°C to 200°C. Comparison of the fluid components and stable isotope (S, H, O, C) composition of the FI between the vein quartz from the ore bodies and from the granite pluton exhibits obvious consistency and/or similarity, which is convincing that the ore-bearing fluids were largely derived from the granites near the deposit. It is also recognized that granites in this area bear a high Au content of 10.39 ppb. REE distribution patterns between the Au-bearing quartz veins and the granite are also consistent or similar. Therefore, the author believes that the Qiqiu No. 1 Au deposit is of a moderate T magmatic hydrothermal origin. (Author's abstract)

HUANG, Weiliang, 1989, Gas-liquid inclusions in Shuguang uranium-bearing granite mass: Diqiu Huaxue 1989, no. 3, p. 260-264 (in Chinese). Author at 290 Res. Inst., Off. Huanan Geol. Explor., PRC.

The gas-liq. inclusions in the Shuguang U-bearing granite are more abundant than in U-barren granite. P gas-liq. inclusions formed at 250-350°, indicating that high-T hydrothermal solns. are pure, with low d (0.73 g/cm^3) and low salinity (1.5-1.6 wt % NaCl). S gas-liq. inclusions formed at 120-350°, showing that U-bearing masses were derived from hydrothermal solns. higher in purity and lower in d (0.83 g/cm^2) and salinity (1.24 wt % NaCl). The solns. contain mainly Ca, Mg, and HCO_3^- at pH ~ 7.07-8.21 and 200°, with high U concns. (0.0017-0.0066 mol). (CA 112:23678x)

HUBERT, P., BENY, C. and TOURAY, J.C., 1989, Application of fluid-inclusion studies to exploration in gold-bearing shear zones: the Cros-Gallet deposit (France) and the Sanoukou prospect (Mali): J. Geochem. Explor., v. 32, p. 57. First author at Bureau de Recherches Géologiques et Minières (BRGM), B.P. 6009, 45060 Orléans Cedex 2, France.

A FI study was undertaken on samples from the Cros-Gallet deposit (Haute-Vienne, Massif Central, France) and the Sanoukou prospect (Kenieba district, Mali), both located in large shear zones several kilometres long. Ore mineral paragenesis for both deposits is similar: early arsenopyrite, pyrite and native Au, and later Pb-Ag-Cu sulfosalts, electrum and galena. Quartz samples were used for FI studies. Nondestructive microthermometry and Raman microprobe analysis were used to characterize the ore-forming fluids. Thermobarometric evolution was similar in both deposits and occurred in two stages:

(1) FI from the H_2O-NaCl-CO_2 (CH_4, N_2) system correspond to a drop of P in a lithostatic regime and accompanied early Au, As ore deposition.

(2) FI from the H_2O-NaCl system correspond to a drop in T and an opening in a hydrostatic regime. It is associated with late Au, As, Pb, Sb ore deposition.

This model was used to estimate the Au potential of quartz samples analyzed by standard global destructive analysis (ICP, Gas Chromatography). At Sanoukou, this method allowed assessment, in a given sample, of the relative importance of the two established stages and demonstrated that Au-rich quartz (Au content >1 ppm) was probably genetically related to the aqueous stage. Utilization of this result could be considered in prospecting. (Authors' abstract)

HUGI, M., DUBESSY, J. and STALDER, H.A., 1989, Fluids associated with As-bearing minerals in the quartzes of the Lengenbach Quarry, Pennine Alps, Switzerland (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 53. First author at Abteilung fHr Isotopengeologie der Univ. Bern, Erlachstrasse, 9a, CH-3012-Bern, Switzerland.

Quartzes have been sampled in a metamorphic dolomite for which the maximum P-T conditions of the metamorphism are estimated ~500-520°C and 4 kbars. Quartzes develop after the peak metamorphism and are associated with the pyrite and complex sulphide minerals (Pb,As, Tl sulfosalts). Three types of FI have been identified: *Type I*: the fluid belongs to the system CO_2-H_2S-N_2-(CH_4)-H_2O system and has a low salinity. Some of these inclusions contain a glass of arseno-sulphide with a composition close to orpiment as determined by both its Raman spectrum and melting T. All these inclusions are contemporaneous with the growth of As-rich sulphosalts. *Type II*: the fluid is mainly aqueous and has a high salinity as shown by the presence of halite dms and a low Te, unknown solids are also present, and CO_2 and CH_4 have been identified. The distribution of this type of inclusion suggests that they are contemporaneous with type I inclusions. *Type III*: are S, are dominantly aqueous and contain CO_2 and H_2S.

Fluid P is ~2.2 kbars at 400°C; the redox state calculated from type I inclusions is close to the Ni-NiO oxygen buffer, and the sulphur fugacity, also calculated from type I inclusions, is in the stability field of pyrite and is consistent with the stability field of orpiment. (Authors' abstract)

HULEN, J.B., GARDNER, J.N., GOFF, F., NIELSON, D., LEMIEUX, M., SNOW, P., MEEKER, K., MUSGRAVE, J. and MOORE, J., 1989, An overview of hydrothermal alteration of vein mineralization in Continental Scientific Drilling Program Core Hole VC-2B, Valles Caldera, New Mexico (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 139.

Completed in the west-central Valles caldera, core hole VC-2B penetrated 1762 m through Plio-Pleistocene intracaldera ignimbrites and Miocene to Pennsylvanian sedimentary rocks into Precambrian quartz monzonite (Fig. 1). Rocks in the upper 800 m and lower 250 m of the hole are extensively altered and veined; intervening Paleozoic siliciclastic and carbonate rocks are essentially unaltered and only sparsely veined. Sericitic alteration, with near-surface kaolin, predominated to 300 m; chlorite-sericite alteration prevails between that depth and 800 m. Deep alteration is primarily propylitic. Identified vein minerals comprise quartz, calcite, ankerite, fluorite, anhydrite, barite, epidote, wairakite, sericite, chlorite, hematite and pyrite, as well as rare rhodochrosite, chalcopyrite, chalcocite, sphalerite, galena, tetradymite(?), stibnite(?), and pyragyrite. FI Th for deeper veins closely match current T (Fig. 1), suggesting recent entrapment of the contained fluids. Shallow Th's, however, are higher than current T, indicating a high-level cooling trend. Shallow inclusion fluids are dilute (<0.7 eq. wt % NaCl—similar to contemporary Valles geothermal reservoir fluid), but deep ones are apparently more saline (up to 2.9%). Therefore, VC-2B may have penetrated "stacked" hydrothermal cells separated by nearly impermeable Paleozoic strata.

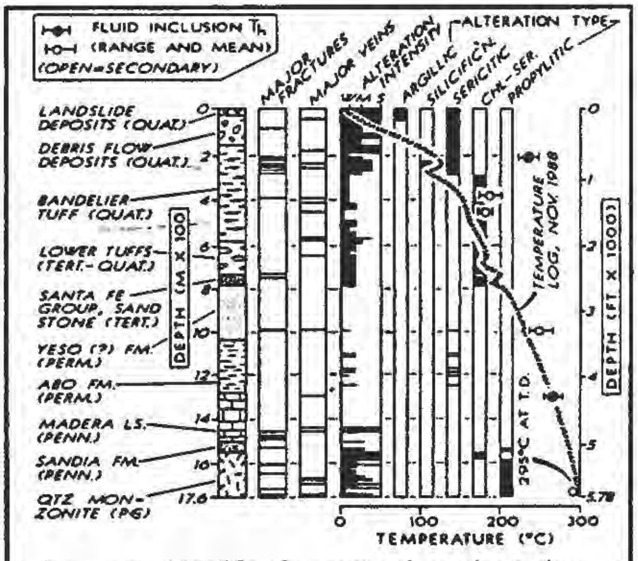


Figure 1. VC-2B: Summerized geologic log

HULSEBOSCH, T.P. and FROST, B.R., 1989, Mineral changes, element mobility, and fluids associated with deep shearing in the Mount Helen Structural Belt, Wyoming, U.S.A., *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 139-150. Authors at Dept. Geology and Geophysics, Univ. Wyoming, Laramie, WY 82071.

The Mt. Helen Structural Belt, located in the Wind River Mountains, Wyoming, formed during high T ductile deformation at about 2.7 to 2.8 Ga. Rock types within the structural belt are dominated by mylonitic orthogneiss which anastomoses around boudins of relatively undeformed orthogneiss. Changes in petrology, chemistry, and fluid inclusions were studied at orthogneiss-mylonitic gneiss transitions. Deformation occurred at ~7000°C [700°C?] and 4.5 to 5.0 kb. At these P-T conditions the dominant petrological change was physical grain size reduction by ductile processes. No major mineral reactions accompanied shearing, and the mineralogy of both orthogneiss and mylonitic gneiss remained basically unchanged. Fluid inclusions within the mylonitic gneiss contain saline brines while inclusions in the relatively undeformed orthogneiss are CO_2-rich. No systematic major element redistribution can be attributed to shearing in the Mt. Helen Structural Belt. Local modification of trace element chemistry is related to minor changes in accessory mineralogy related to the formation of sphene. High T ductile deformation in the presence of aqueous brines is not a sufficient mechanism to modify the chemistry of the deep crust when major mineral reactions are absent. (Authors' abstract)

HURAI, Vratislav, 1989a, Calculation of room temperature phase relations in H_2O, H_2O-NaCl, and H_2O-CO_2-NaCl fluid inclusions (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 13-20. Author at Geol. Inst., Comenius Univ., 842 15 Bratislava, CSSR.

Bodnar (1983) published the method of calculating volumes of irregular, three-dimensional inclusions, based on measuring diameters of regular phases (gas bubble, halite cube) and Th. There is a possibility to solve the problem as a reverse task: once an inclusion volume, density of homogeneous fluid and phase densities at room T are known, we can calculate phase volumes or ratios at room T.

The method is applied here to the H_2O, H_2O-NaCl and H_2O-CO_2-NaCl inclusions, because they are heterogeneous at room T, their properties are described by equations of state in a wide range of PT conditions and not least they occur in most geological environments. (From author's text by E.R.)

Standard capsule-shaped FI drawings are presented showing the relative phase volumes at room T for various values of P, V, T, and X. (E.R.)

HURAI, V., 1989b, Basic program for interpretation of microthermometric data from H_2O and H_2O-NaCl fluid inclusions: Computers & Geosci., v. 15, no. 1, p. 135-142. Author at Geol. Inst., Comenius Univ., 842 15 Bratislava, Czechoslovakia.

Empirical equations fitted to the experimental data of R. Hilbert and M. Gehrig have been used in a BASIC program to locate T/P coordinates of isochores for H_2O and H_2O-NaCl fluids to 700°C. The program also permits calculation of P-V-T-X relations at homogenization point of FI. Isochoric coordinates based on the data of R. Hilbert and M. Gehrig show increasing divergence from other published tables towards higher T, P and NaCl contents. (Author's abstract)

HURAI, Vratislav, FRANCU, Juraj, BAJOVA, Ludmila and **GAVACOVA, Hilda**, 1989, Hydrocarbon inclusions in "Marmarosh diamonds" from flysch sediments of eastern Slovakia (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 5-6. Authors at Geol. Inst., Comenius Univ., 842 15 Bratislava, CSSR.

Quartz with characteristic dipyramidal habits - "Marmarosh diamonds" - were studied at the Velky Lipnik locality, where they are liberated into alluvial and eluvial sediments from fissures and veinlets in sandstones of the Eocene age, belonging to flysch sediments of the central Carpathian Paleogene. The occurrence of Marmarosh diamonds is confined here to the close contact of flysch sediments and the klippen belt. Fissures and thin quartz-calcite veins containing Marmarosh diamonds usually follow NE-SW or NW-SE direction of the main tectonic elements that very likely originated between Eocene and Oligocene. The oldest (E-W) and youngest (N-S) tectonic structures have not been found to contain mineralization.

FI in Marmarosh diamonds are composed of water-rich phase of very low salinity (no more than 0.5 wt % NaCl eq.), very dense supercritical CH_4-rich gas, liquid-like higher hydrocarbons and bitumens of reddish-brown to black color. Water and CH_4-rich gas very often are presented in separate inclusions, however, in many cases various gas-to-liquid ratios within inclusions indicate immiscibility between water and CH_4-rich phase during entrapment of inclusions.

Th of water-rich inclusions range from 140 to 370°C showing a distinctive peak at 160°C. Th values for CH_4 inclusions, monophase at room T, span the interval between -106 and -83°C with Th to liquid. The Th values are often higher than the critical point for pure CH_4 (-84.6°C) thus suggesting the presence of additional components with higher CP (higher hydrocarbons, carbon dioxide). This is also supported by the formation of octahedral phases, probably CO_2-solids, on freezing of CH_4 inclusions. Melting of the solid phase occurs always before homogenization point of an inclusion is reached. Providing only CH_4-CO_2 binary system be presented within inclusions, T of phase transformation would indicate less than 20 mol % of CO_2 in the mixture (Herskowitz-Kisch 1984). There is a linear correlation between Tm of CO_2-solid(?) and Th of inclusions. The presence of CH_4 is evidenced in complex inclusions by the formation of the clathrate with decomposition T between 5-22°C with a strong maximum at 13-16°C.

Chemical composition of water-rich phase has been checked by means of atomic absorption analyses of leachates from crushed quartz crystals. Analyses showed the presence of Na > K > Mg > Ca with Na/K wt. ratio = 2. Composition of inclusions aqueous solution is entirely different from recent mineralized waters of the area.

Raman analysis of an individual CH_4-rich monophase inclusion (J. Dubessy and J. Durisova at CREGU, Vandoeuvre, France) failed to confirm the presence of CO_2 because of strong fluorescence, however limited amounts of H_2S (2.5 mol %) and C_2H_6 (2.5 mol %) have been recognized. The presence of C_2H_6 must be considered with a great deal of uncertainty. Raman analysis also revealed the presence of coal-like coating on inclusion walls otherwise invisible under polarization microscope.

Because of the immiscibility phenomena during entrapment of inclusions, minimum Th of water-rich inclusions (140-160°C) are presumed to be close to real Tt. Minimum P of CH_4-rich phase at this T range may have reached 500-1000 bars assuming that densities of CH_4-rich phase were between 0.2-0.25 g/cc. Unfortunately, there is no exact theoretical or experimental basis according to which densities of such complex gas mixtures could be estimated.

The composition of inclusions strongly suggest their diagenetic origin, however, relatively high fluid P might have indicated the effect of hydraulic fracturing responsible for formation of fissures and veins containing Marmarosh diamonds. The effect could have been invoked by the thermal decomposition of higher hydrocarbons in the depth. Thermal effect of an intrusive magmatic body of Miocene age is the most probable explanation, because of the presence of such bodies exposed to the surface in few kilometers distance (Sczawnica, Poland) from the area under consideration.

The results presented here not only add some more data about Marmarosh diamonds that were studied in details using inclusion microthermometry mainly in the USSR (e.g., Zacicha et al. 1985), but have certain economic importance. FI studies of Marmarosh diamonds may be used in oil-gas prediction modelling of the area studied, because of bringing information about degree of thermal metamorphism of the sediments and yielding data about composition of gas that very probably should be expected within gas-oil test bore holes. (Authors' abstract)

REFERENCES

Herskowitz, M. - Kisch, H.J. 1984: An algorithm for finding composition, molar volume and isochores of CO_2-CH_4 FI from Th and Tfm (for Th < Tfm). Geoch. Cosmoch. Acta 48, 1581-1587.

Zacicha, B.V. - Kvasnica, V.N. - Galij, S.A. - Matkovskij, O.I. 1984: Tipomorfizm mineralov polimetallicheskich i rtutnych mestorozhdeniy Zakarpatiya. Naukovn Dumka, Kijev, 165 p.

HUTCHINSON, R.M., 1988, Fluid inclusion studies of Camp Bird and 8572 veins (abst.), *in* R.M. Hutchinson (ed.), Epithermal Base-Metal and Precious-Metal Systems, San Juan Mountains, Colorado: SEG Guidebook Series, v. 3, p. 45.

Fluid inclusion studies have been initiated on quartz and fluorite from three levels of Camp Bird vein, i.e., 14-Level, 8-Level, and 5-Level. Sphalerite and quartz from 8572 vein, a northwest-trending vein, have also been studied. Four vein phases of mineralization have been recognized in Camp Bird vein. These are: (1) early quartz-sulfide (Stage I), concurrent or slightly later quartz-hematite (Stage II), gold-quartz (Stage III), and barren quartz (Stage IV). The principal ore minerals are pyrite, chalcopyrite, galena, sphalerite, and Au in the native state. Quartz and hematite are major gangue minerals. Paragenetic position of a fluorite stage is as yet undetermined, but cubes of fluorite are capped by fine-grained quartz and spatially closely associated with the early quartz-sulfide stage. Samples so far analyzed for FI are quartz and fluorite from 1680 West Camp Bird vein and fluorite from 1450 East Camp Bird vein, quartz and fluorite from 8-Level, and fluorite from 5-Level. P FI are present in both the quartz and fluorite from all three levels. Comb quartz on 14-Level does not have constant L/V ratios, thus indicating T less than 200°C. The comb quartz also has lots of P FI and zoned growths with L/V-rich inclusions, thus showing evidence of boiling. T could have ranged from 200-270°C. A series of test measurements of 10 data points on P inclusions on fluorite from Sample No. 14-1 (14-Level) of 1450 East Camp Bird vein gave a minimum average T of formation of 175-180°C. Tm ice averaged -0.5°C which converts to about 0.9 wt % NaCl eq. salinity. Epithermal environment FI at RT typically contain a H_2O liquid phase and a vapor bubble and also have a low salinity. Sphalerite from the N50°W trending

8572 vein has isolated P crystal stages, and on the basis of bubble size, the sphalerite formed at ~250°C. Preliminary FI studies of Camp Bird vein and the associated northwesterly-trending 8572 vein so far indicate both veins to be a typical epithermal paragenetic assemblage. (Author's abstract)

HYLAND, M.M. and BANCROFT, G.M., 1989, An XPS study of gold deposition at low temperatures on sulphide minerals: Reducing agents: Geochim. Cosmochim. Acta, v. 53, p. 367-372.

ILTON, E.S. and EUGSTER, H.P., 1989, Base metal exchange between magnetite and a chloride-rich hydrothermal fluid: Geochim. Cosmochim. Acta, v. 53, p. 291-301. First author at Amer. Museum of Natural History, Dept. Min. Sci., Central Park West at 79th St., New York, NY 10024-5192.

Base metal exchange reactions between magnetite and a supercritical aqueous chloride solution have been experimentally calibrated at T = 600 to 800°C, P = 2 kb, and total chloride = 2.06 M. Results for the Cd-Fe and Cu-Fe exchange reactions indicate that both Cd and Cu are extremely partitioned into the fluid with respect to Fe and very strongly partitioned into the fluid with respect to Zn and Mn. The experimental results suggest that even minor to trace concentrations of these base metals in natural magnetites indicate strong enrichment of Zn, Mn, Cu, and Cd relative to Fe in chloride-rich hydrothermal fluids. In particular, Kd_{Mn-Fe} was applied to magnetites from skarn deposits. Calculations at 360 and 420°C suggest that skarn fluids in equilibrium with magnetites containing only minor concentrations of Mn can have Mn/Fe ratios greater than 1. (From authors' abstract by E.R.)

IMMITT, J.P., 1987 (dated 1985), Skarn-type and epithermal-type mineralization near the San Carlos caldera, northeast Chihuahua: Universidad Nacional Autonoma de Mexico, Instituto de Geologia, Boletin 103, 76 pp. (in Spanish, English abstract).

The San Carlos Pb-Zn-Ag skarn deposit and several Pb-Zn-Cu-fluorite epithermal vein prospects are located along the boundary of the San Carlos caldera near Manuel Benavides (San Carlos) in northeastern Chihuahua, Mexico. Pre-mineralization calc-silicate assemblage has been replaced by a metasomatic assemblage consisting mainly of magnetite, calcite, galena, and sphalerite. Precipitation of ore minerals took place when acidic magmatic hydrothermal fluids interacted with the dominantly carbonate country rocks. Retrograde serpentine alteration of forsterite and diopside is the only indication of the pre-mineralization metamorphosed lithologies.

The epithermal vein prospects occur near the northwestern margin of the caldera mainly along normal faults near the apex of the La Consolación dome. This dome was probably formed during emplacement of another peripheral intrusion believed to be present at depth. Veins occur in marbleized Lower Cretaceous shale and argillaceous limestone and in a hydrothermally altered caldera-related Tertiary rhyodacite flow. Ore deposition resulted from circulation and cooling of metal- and fluorine-bearing hydrothermal fluids. Fluid inclusion data indicate a range from 317-142°C and in salinity from 5.7-2.8 eq. wt % NaCl, with both generally decreasing in younger minerals.

Mineralization in the San Carlos area is spatially, and may have been temporally associated with development of the San Carlos caldera. It may have been controlled by the availability of heat and hydrothermal fluid from caldera-related igneous activity, ease of fluid movement along caldera-related structures, and the presence of reactive host rocks. (From author's abstract by E.R.)

INGEBRITSEN, S.E. and BREDEHOEFT, J.D., 1989, Degassing of carbon dioxide as a possible source of high pore pressures in the crust (abst.): Eos, v. 70, p. 1378.

IRWIN, J.J., BOHLKE, J.K. and PETERSON, J.W., 1989, Microanalyses of halogens (Cl, Br, I) and noble gas isotopes (Ar, Kr, Xe) in synthetic fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A285-286. First author at Physics Dept., Univ. California, Berkeley, CA 94720.

A sensitive low-blank mass spectrometer was modified to analyze small quantities of Ar, Kr, and Xe isotopes extracted from irradiated fluid inclusions (FI) in minerals. FI-bearing chips measuring roughly 4x3x1 mm were neutron-irradiated to produce Ar, Kr, and Xe isotopes from K, Cl, Br, and I. Both natural and neutron-induced noble gases were then released from small clusters of FI by laser ablation and analyzed in the mass spectrometer. Data from synthetic FI of known compositions indicate that the relative abundances of K, Cl, Br, I, Ar, Kr, and Xe, and the isotopic compositions of Ar, Kr, and Xe, can be determined accurately from noble gas measurements of $<10^{-11}$ liter of fluid (corresponding to a single cubic FI <30 microns across).

Two types of synthetic FI were prepared at 700°C, 2-3 kb, in fractured quartz: (1) a mixed salt solution, mainly NaCl, with 1.0 m Cl, and (2) a 0.6 m KCl solution. Analyses of Synthetic Type 1 indicate that FI were trapped from a single homogeneous fluid phase consisting of the mixed salt solution with uniform concentrations of dissolved air gases. Analyses of Synthetic Type 2 indicate that a heterogeneous population of air-rich fluids were trapped with the KCl solution, probably because the solution failed to displace all of the air in the cracks before they annealed. Ar, Kr, and Xe extracted from both samples have atmospheric isotopic compositions, except for the neutron-induced $^{38}Ar_{Cl}$, $^{39}Ar_K$, $^{82}Kr_{Br}$, and $^{128}Xe_I$. Relative neutron reaction yields from K, Cl, Br, and I calculated from the synthetic FI data agree (within ±10-20%) with those calculated from neutron cross-sections and hornblende monitors. Both of the hydrothermally treated quartz samples yielded variable amounts of excess Xe that is not correlated with the FI components, whereas untreated quartz from the same stock yielded insignificant amounts of all measured gases. Some natural samples also have yielded excess Xe of uncertain origin.

These data, as well as numerous analyses of natural FI, clearly demonstrate that quantitative analyses of dissolved gas and electrolyte components can be obtained simultaneously from minute inclusions of fluids in minerals. Further experiments with synthetic FI will permit routine calibration of irradiation parameters for natural FI analyses and will elucidate the mechanism of incorporation of excess Xe in hydrothermal phases. (Authors' abstract)

ISAKHODZHAEV, B.A., 1988, Mineral formation temperature of the major antimony ore deposits in southern Fergana [USSR]: Usloviya Obraz. i. Zakonomernosti Razmeshch. Mestorozhd. Polez. Iskopaemykh, Tashkent 1988, p. 69-72 (Russ). From Ref. Zh., Geol. 1989, Abstr. No. 4ZH149. Title only translated. (CA 111:118324)

ISKANDAROV, F.Sh. and **FAIZIEV, A.R.**, 1989, About some peculiarities of phase boundaries of fluid inclusions in fluorite (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 33. Authors at Tadjik State Univ., Dashanbe, 734016, USSR.

Syngenetic FI were found in fluorite from carbonatites in the Pamirs. At the room T the inclusion boundaries remain imperceptible, that is, the refractive index of the liquid is approximately equal to the refractive index of the fluorite (Fig. 1). As it is known, the refractive index of fluorite varies from 1.434 to 1.457, depending on the content of impurity elements, especially yttrium. The refractive indices of the Pamirs fluorites are 1.438-1.442. For determination of the chemical composition of the FI we conducted some experiments, based on the studies of refractive indices of artificial salt solutions.

In fluorites the inclusions contain, together with H_2O-CO_2 solution and the microcrystals of isotropic and anisotropic minerals, the products of crystallization of oversaturated salt-water-carbon dioxide solution.

The experimental investigations show that saturated solutions of KCl and NaCl have refractive indices of 1.379 and 1.369, respectively, i.e., markedly less than the refractive index of fluorite. The saturated solutions of $MgCl_2$ and K_2CO_3 have corresponding refractive indexes 1.362 and 1.420, which again are less than that for fluorite. A saturated solution of $CaCl_2$ has a refractive index of 1.468, more than CaF_2.

The experimental data show the linear dependence of solution refractive index on the salt concentration (Fig. 2). From Fig. 2 it is seen that the refractive index, corresponding to fluorite one, is characteristic for a 34% solution of $CaCl_2$.

Consequently, the liquid phase of the inclusions in fluorites from the Pamirs carbonatites is composed mainly of calcium chloride. The total concentration of chlorides in these inclusions is estimated to be 75 wt % at Th 700°C. (Authors' abstract)

Fig.1

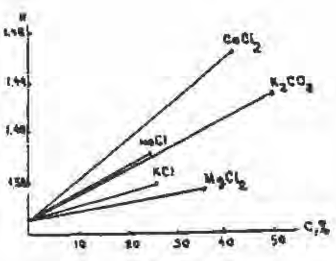


Fig.2

ISTRATE, G. and **ALTHAUS, E.**, 1988, $CH_4 \pm N_2$ high density fluids in inclusions in granulites from Calabria, Italy (abst.): Fortsch. Mineral., v. 66, Beiheft 1, p. 74 (in German).

A 7-km thick sequence of lower crust metamorphosed under granulite-facies conditions (800°C, 7-8 kbar) occurs in Calabria. The upper part is a transition to the amphibolite facies (650-700°C). The following rock types from the massif of Sila were studied: (1) felsic granulite/stronalite, leptinite, (2) hypersthene-garnet-plagioclase granulite, (3) metapelitic granulite gneisses, (4) calc-silicate rocks, and (5) anatectic mobilisates in the form of concordant and discordant leucosomes, locally passing in pegmatoids. Granulites bear only rare and very small inclusions; all contain low amounts of water, but mainly $CH_4 \pm N_2$ and CO_2. Hypersthene-garnet-plagioclase granulite and certain felsic granulites are extremely poor in P inclusions. Matrix quartz grains bear rare 1-5 µm $CH_4 \pm N_2$ fluid inclusions and even rarer H_2O-filled inclusions. The highest metamorphosed granulites bear almost exclusively $CH_4 \pm N_2$ inclusions, very rarely accompanied by water solution inclusions of very high salinity, with not only NaCl but also with salts of Mg and Ca. Th of -82 to -147°C indicate the presence of CH_4, but numerous Th data between -160 and -180°C may also suggest the occurrence of N_2. The measured Th suggest the densities of 0.4 g/cm^3 for methane or 0.7 g/cm^3 for nitrogen. The appropriate isochores show 6.5-7 kbar at ca. 700°C. Tm of CO_2-inclusions range from -56.6 to -65°C, sometimes even to -70°C, meaning an admixture of $CH_4 \pm N_2$. Th in L phase at -20°C to -45°C indicate densities of 0.9 to 1.1 g/cm^3 or 6-8 kbar at 700°C. A peculiar feature of the fluids in Calabria is the prevalence of the $CH_4 \pm N_2$ fluids over the typically granulite-facies fluids consisting mostly of CO_2. (Authors' abstract translated by A.K.)

ISTRATE, Georg and **ALTHAUS, Egon**, 1989, Methane and nitrogen in granulite facies rocks from the Sila Massif, Calabria, southern Italy: N. Jb. Miner. Mh., 1989, no. 3, p. 97-108.

Granulite facies rocks are generally formed under the conditions of reduced H_2O fugacity at relatively high T and P. Usually, CO_2 is believed to be the dominant species responsible for the low fH_2O. In many granulite areas, e.g., Norway, Finland, Siberia, India and Sri Lanka, Tanzania, etc., this was documented by the investigation of FI which were believed to contain the original co-genetic fluid phases.

In granulitic and other lower crustal rocks from the Sila Massif in Calabria/southern Italy, FI contain only very small to moderate amounts of CO_2. In many samples CO_2 is entirely absent. The fluid regime is dominated, however, by other constituents diluting the ubiquitous aqueous fluid. By microthermometry and laser Raman analysis unambiguous evidence has been found that these components are nitrogen and methane. (Authors' abstract)

ITARD, Y., CHAMPENOIS, M., CHEILLETZ, A. and **RAMBOZ, C.C.**, 1989, Volume estimation of fluid inclusions using an interactive image analyzer (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 54. Authors at CRPG, CRPG-CNRS BP 20, 54501 Vandoeuvre l0s Nancy, France.

The natural diversity of FI shapes limits the use of standard charts for the determination of their degree of filling. Mathematical morphology has been applied to FI, using the Image Analyzer system which allows the operator to digitize the geometry of selected inclusions. A program has been written to calculate the degree of filling from the digitized section. The program extracts the skeleton, i.e., the thin line inside the object which expresses its external shape (like the nervures of a leaf). The calculation of the inclusion volume is based on the hypothesis that the inclusion has a rotation symmetry around each skeleton point (Ponctual Rotation Symmetry: P.R.S.).

The volume is calculated as the sum of the volume of each cone frustrum limited by the disks, of the sphere(s) and/or the spherical domes at the ends of the skeleton. For volumetric estimations, the interactive system allows one to choose, within a population of FI with well characterized microthermometric properties, the inclusion which best fits the hypothesis of P.R.S. The method has been applied to cylindrical, euhedral and more complex synthetic FI in the H_2O-NaCl and H_2O-NaOH systems. Errors on the calculated volumes are estimated by comparing the degree of filling calculated by the program with the one derived from an interpretation of the microthermometric properties of individual inclusions. (From authors' abstract by E.R.)

IVANOVA, G.F., KOPNEVA, L.A. and **HOELL, P.**, 1989, Study of fluid inclusions in minerals from the Felbertal stratified scheelite ore deposit (Austrian Alps): Geokhimiya, 1989(6), p. 785-797. Authors at Inst. Geokhim. Anal. Khim., Moscow, U.S.S.R.

Based on a study of FI in minerals of the stratified scheelite deposit Felbertal, the following were determined: Th—quartz 310 to 130°, beryl 310 to 265°, scheelite 310 to 270°, calcite 270°, fluorite 287 to 157°C; concentration of solutions—15 to 26 wt % eq. NaCl; Tm CO_2, -56.6 to -57.3°C; and isotopic composition of carbon of CO_2 of inclusions in quartz, -9.3 to -10‰. In the minerals of ore zones with different structural-tectonic position of the Felbertal deposit, a homogeneity of values of the above-listed characteristics was discovered. A comparison of the main characteristics of fluid of Felbertal ore zones localized within areas of more ancient deformations and minerals of Alpine veins localized in the zone of young Alpine deformations has been made. (Authors' abstract)

IVANOVA, G.F. and **NAUMOV, V.B.**, 1989, The main parameters of hydrothermal solutions forming tungsten deposits: Geokhimiya 1989, no. 7, p. 925-935 (in Russian, English abstract).

In the result of study of fluid inclusions in wolframite, scheelite, quartz, topaz, fluorite and carbonates of various composition the main parameters of hydrothermal solutions during the ore and post-ore stages of tungsten deposits' formation have been determined. It has been shown on the example of 23 deposits that composition of wolframite can not be used as geothermometer and geobarometer. Differences in physico-chemical parameters of solutions deposited scheelite and wolframite in the deposits of various genetic types have been found. (Authors' abstract)

IZAWA, Eiji and **CUNNINGHAM, C.G.**, 1989, Hydrothermal breccia pipes and gold mineralization in the Iwashita orebody, Iwato deposit, Kyushu, Japan: Econ. Geol., v. 84, p. 715-724.

Use data from the literature only. (E.R.)

JACKSON, N., KNOX, D., DOMINY, S., HOWE, J., BROSTOW, C. and **FALLICK, A.**, 1989, Geology of the primary china clay deposits of SW England (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 36-37. First author at School of Geological Sciences, Kingston Polytechnic, Kingston upon Thames, U.K.

The china clay deposits of SW England are one of the main sources of quality kaolin in the world with an annual production of 3MT worth more than £200M ($350M US). The primary deposits are the result of *in situ* hydrothermal alteration of variably porphyritic, coarse- and medium-grained, two mica, tourmaline-bearing monzogranite, syenogranite and albite-microcline topaz granites, which form the roof of the Cornubian batholith. Furthermore, all the main production centres are coincident with regional Li anomalies: an indication that processes leading to Li enrichment in the granites also influence the localisation and formation of china clay deposits. Detailed investigations have shown that the geometry of the deposits is influenced by the distribution of cupolas of late, medium-grained, B-rich microgranites and important structural features such as faults, fractures, shear and crush zones, vein swarms and hydrothermal breccias. Intense argillic alteration results in a reduction in bulk density from ~2.6 to 2.1 and leaching of most of the Na, K and Ca.

Evidence of hydrothermal activity within zones of argillic alteration is ubiquitous, and in some deposits there is a direct correlation between the abundance of quartz and tourmaline veins and the intensity and depth of alteration. Fluid inclusion studies indicate a complex pattern of fluid/rock interaction. The earliest episode of hydrothermal activity was responsible for pervasive alteration (S tourmaline, Na-K feldspar and mica), micro- and macroscopic hydraulic fracturing, sheeted vein swarms, tourmalinite dykes and lodes, and hydrothermal breccias. These rocks formed in a plutonic hydrothermal system from hot (> 200 to >500°C), saline (<10 to 40 eq. wt % NaCl) fluids which locally show evidence for unmixing. These fluids were superseded by cooler (150+/-50°C), low to moderate salinity (<10 eq. wt % NaCl) fluids, which were probably responsible for primary argillic alteration. Crystallite growth textures suggest that much of the kaolinite has grown/recrystallized in the presence of aqueous fluid in a near-surface environment. Kaolinites display a restricted range in $\delta^{18}O$ (17.9 to 22) and δD (-60 to -73) and cluster near the reference kaolinite weathering line.

Fluid movement must have been pervasive and the systems must have been open to surface in order to facilitate removal of vast quantities of material leached from the granite. The size, geometry and geological/hydrothermal features of the more intensively studied clay deposits suggest that there are many similarities with modern epithermal-geothermal systems. (From authors' abstract by E.R.)

JACKSON, N.J., WILLIS-RICHARDS, Jonathan, MANNING, D.A.C. and SAMS, M.S., 1989, Evolution of the Cornubian ore field, southwest England: Part II. Mineral deposits and ore-forming processes: Econ. Geol., v. 84, p. 1101-1133. First author at School of Geological Sciences, Kingston Polytechnic, Kingston-upon-Thames KT1 2EE, U.K.

The Cornubian ore field of southwest England is spatially associated with the roof of an S-type, ilmenite series, high heat production monzogranite batholith. Three metallogenic stages can be recognized within the ore field: a prebatholith stage (300-400 Ma), when minor strata-bound Fe-Mn oxy-hydroxide and Fe-Cu sulfide synsedimentary deposits formed; a synbatholith stage (270-300 Ma), or main-stage event, when hydrothermal deposits of Sn-Cu-As-Fe-Zn-Pb were formed; and a postbatholith stage (Mesozoic-Cainozoic), when epithermal vein deposits of Pb, Ag, Sb, Ba, Zn, Fe, U, Co, Ni, and Au, and hydrothermal-supergene kaolinite deposits, formed.

The main-stage event was related to the protracted crystallization and cooling history of the batholith. Several compositional features of the granite were important in promoting base metal mineralization, namely, (1) the Sn-rich nature of the magma, which constituted an important metal reservoir; (2) moderately reducing conditions during crystallization; (3) a peraluminous evolutionary trend, which both promoted the retention of base metals in residual melts; (4) high B contents, which enhanced water solubility in the melt and thus increased the availability of magmatic fluid in residual magmas; and (5) high contents of heat-producing elements, which exerted a significant influence on the crystallization history of the batholith and led to the maintenance of residual melts at depth for 10 to 20 Ma after initial emplacement.

Main-stage mineralization phenomena are focused on the roof and margins of the major plutons, buried ridges, and satellite stocks of a large batholith. The principal types of mineral deposit are lodes and replacement deposits containing cassiterite and Cu, As, Fe, and Zn sulfides, and sheeted greisen-bordered vein swarms containing wolframite and cassiterite with minor Sn, Cu, Fe, As, and Zn sulfides. The ore field represents a fossil plutonic (-3,000 to -4,000 m) hydrothermal system in which hot (200°-500°C), moderately saline (10-30 eq. wt % NaCl) fluids of mixed meteoric, magmatic, and metamorphic origin were circulating. Meteoric fluids were drawn in from the wall rocks adjacent to the batholith and convected through subvertical fractures which were concentrated along the axial trace of each compartment of the batholith. It is postulated that most of the mineralization formed where metal and sulfur-bearing fluids of essentially meteoric origin mixed with metal and sulfur-bearing fluids of magmatic departure. Convective flow was controlled by the shape and depth of the batholith and the local and regional fracture systems which constituted high permeability corridors. These fracture systems were produced by the hydraulic and tectonic expansion of faults and fractures formed prior to and during batholith emplacement and the hydraulic-tectonic expansion of cracks resulting from thermal stresses.

Erosion of the batholith roof in the early Mesozoic led to an increase in epithermal activity and the superimposition of epithermal systems on the earlier plutonic hydrothermal systems. Epithermal activity continued throughout the Mesozoic and Cainozoic and a wide variety of vein mineralization, including Fe, Ba-Pb, Pb-F, Pb-Sb, U-Ni-Co-Ag-As-Bi, and Au-Se-Pb-Ag-Hg, was emplaced. Epithermal hydrothermal systems also played an important role in the development of the economically important, in situ china clay deposits. Epithermal fluids (less than 200°C) had a wide salinity range (1-27 eq. wt % NaCl). Vein deposits are predominantly hosted by north-south-trending faults or extensional fractures which are often linked to northwest and north-northwest-trending wrench faults. Contemporary hot spring activity attests to the continuing dynamism of the environment and highlights the superimposed complexity of hydrothermal systems associated with high heat production granite batholiths. (From authors' abstract by E.R.)

JACOBSON, R.S., 1986, A fluid inclusion study of the Tayoltita district, Mexico: BA honors thesis, Harvard and Radcliffe Colleges, 73 pp.

Precious metal production from the veins of the Tayoltita mine total more than 2x10^5 kg of Au and more than 10^7 kg of Ag. They are the most productive in the Sierra Madre Occidental. Ore deposition at Tayoltita is controlled by fractures that have been mineralized by hydrothermal circulation. Traditional concepts of hydrothermal systems predict that ore deposition may occur in part due to ascending fluids cooling as they rise through the rock column. Ore fluid composition should change continually in response to a falling T and P regime, as well as by reactions with wallrock.

The paleo-T distribution at Tayoltita, as indicated by FI measurements, contradicts this theory. Th of FI in quartz veinlets increase with distance from large veins. Th also increase toward shallower depths in the veins. In general, it appears that warm fluids (260°C) permeated hotter rocks (~300°) and that ore deposition at Tayoltita is associated with rising fluid T. This strongly suggests that controls on ore deposition are not simply falling T, but rather that P or more complex chemical equilibria dominate the process. (Author's abstract)

JAHODA, R., 1988, Geology, and genesis of auriferous hydromagmatic breccias and related deposits in northwestern Spain: PhD dissertation, Univ. Southampton.

Late Hercynian Au-bearing hydromagmatic breccias occur in dolomitized Vegadeo Limestone and Cabos Series metasediments, both of early Palaeozoic age. The breccias are confined to jogs (side-steps) and areas of imbrication along major strike-slip faults.

Hydrothermal alteration leading to hydromagmatic brecciation in dolomitized Vegadeo Limestone (Abaniella-Iboyo) commenced with biotitization and albitization and was followed by the replacement of dolomite by silica (jasperoid). The silicification generated an impermeable cap, and the ensuing increase in P(H_2O) and P(CO_2) culminated in hydromagmatic brecciation. The early stages of brecciation were characterized by the production of low-energy solution breccias in which fragments were corroded but show very little displacement. The main stage of hydromagmatic brecciation was caused by high-velocity fluid-streaming of a CO_2-rich aqueous fluid and the resultant breccias contain angular and subrounded fragments of various lithologies. The breccias are commonly cemented by the hydrothermal minerals dolomite, quartz, albite, biotite, and sericite, accompanied by pyrite and minor tetrahedrite. Late-stage fluids altered biotite to chlorite, deposited chalcedony, and caused locally intense sericitization.

Hydromagmatic breccias in the Cabos Series metasediments (Monterroso) were also emplaced by high-velocity fluid-streaming and are composed of dolomite-albite(-quartz-apatite) plus quartzitic rock fragments. Pyrite and arsenopyrite occur disseminated throughout the breccia; the Au occurs mostly as free Au and as grains up to 3 mm.

Both the Abaniella-Iboyo and Monterroso breccias are accompanied by gabbroic intrusions exhibiting chemical characteristics equivalent to those of continental basaltic magmas.

$\delta^{18}O$ values of albite from both prospects range between 10.25 and 10.68‰, and isotope T based on a primary magmatic water-source indicate crystallization T between 350° and 400°C. $\delta^{18}O$ values of dolomite from dolomite-albite breccias average 1.57‰ and isotope T based on mixed magmatic-metamorphic fluids indicate T between 270° and 350°C.

In conclusion, identification of gold exploration targets in northwestern Spain requires an evaluation of the interactive roles of magmatism, fluid evolution and host rock-type within fault jogs and zones of strike-slip imbrication. (From author's abstract)

JANG, B-A., WANG, H.F., REN, Xiaofen and KOWALLIS, B.J., 1989, Precambrian paleostress from microcracks and fluid inclusions in the Wolf River batholith of central Wisconsin: Geol. Soc. Am. Bull., v. 101, p. 1457-1464. First author at Dept. Geology and Geophysics, Univ. Wisconsin-Madison, Madison, WI 53706.

A strongly developed set of healed microcracks striking ~NW-SE is present at 5 of 6 sample localities within the 1450 ± 20 Ma Wolf River batholith of central Wisconsin. Other minor sets are present but are less well defined. FI in healed microcracks show melting T in 2 groups: 0°C, indicating nonsaline water, and -3 to -30°C, suggesting salinities >4.5%. The *in situ* Tt of FI, calculated from Th, show a consistent 250-400°C for all the sets of healed microcracks. Several Rb-Sr dates of ~1440 Ma on biotites from the Wolf River batholith suggest that the 300°C blocking T of biotite was reached very soon after intrusion and that no reheating event after primary cooling took place in the batholith. The FI data and Rb-Sr data interpreted together suggest that cracks were probably generated and healed during the initial cooling of the pluton, starting at near 400°C. The preferred orientation of these microcracks implies that the maximum horizontal stress was NW-SE for this region about 1400-1450 Ma. A similar orientation of a major joint set in the area also might be correlated with the same event. Strongly developed N20°W FI planes in the Illinois deep borehole UPH-3, ~250 km to the SW, with similar-age bedrock, may reflect a more distal effect of this same stress field.

The NW-SE orientation for the maximum horizontal stress direction during the cooling of the Wolf River batholith is subparallel to the proposed orientation of the paleostress field prior to the emplacement of the Wolf River batholith during an unnamed event that deformed upper Proterozoic quartzites, and it is consistent with a long period of continental collision and accretion, which formed NE-trending belts along the southern and SE margin of the continent. The orientation of the regional stresses may have remained fairly constant during much of the period from Penokean to the start of the Keweenawan, when the maximum regional horizontal stress changed from a NW orientation to a NE one. The data show that even in periods of relative tectonic quiescence, such as during intrusion of the Wolf River batholith, microcracks may provide a record of paleostress orientations. (Authors' abstract)

JENSENIUS, Jørgen and **MUNKSGAARD, N.C.**, 1989, Large scale hot water migration systems around salt diapirs in the Danish Central Trough and their impact on diagenesis of chalk reservoirs: Geochim. Cosmochim. Acta, v. 53, p. 79-88. First author at Koninklijke/Shell Explor. en Prod. Lab., Volmerlaan 6, 2288 GD Rijswijk ZH, The Netherlands.

Fracture filling calcite from the piercement fields of East Rosa, Skjold, Rolf, North Arne, Nils and Vagn (directly underlain by salt diapirs) and the dome field Dan (overlying a deep seated salt structure) have been studied by fluorescence and cathodoluminescence microscopy, FI microthermometry and C and O isotopes. The C and O isotope compositions of the reservoir matrix chalk have also been measured. The T estimates obtained from FI data suggest that the fracture filling calcite of the piercement fields precipitated during hot water flushing of the reservoirs. The flushing system only existed around the salt diapirs and was probably related to expulsion of overpressured fluid from the surrounding sediments. The thermal anomaly and the faults associated with the diapirs probably were important factors in focusing the ascending water. By combining FI thermometry with O isotope data for the fracture filling calcites ranges of O isotopic values of the flushing water are deduced: in Skjold, Rolf, North Arne, Nils and Vagn: $\delta^{18}O$ = -1 to +7‰ SMOW, which combined with data on FI salinities suggest that the flushing waters were responsible for substantial salt dissolution. Lower $\delta^{18}O$ values with shallower depth of burial suggest that the porosity of chalk in the shallower fields was more severely reduced by calcite cementation during the flushing event than in the deeper fields. In the case of North Arne, Nils, Vagn and Dan, $\delta^{13}C$ values of the fracture filling calcites are similar to those of normal chalk (0.5 to 3.5‰). However, calcites from Rolf, Skjold and Est Rosa are depleted by -1.8, -6.2 and -16.7‰, respectively. Only in East Rosa is the matrix chalk itself depleted in ^{13}C (range: -2.0 to +0.7‰). The low $\delta^{13}C$ values are interpreted as the result of biodegration. Sulphate originating from the underlying diapirs was flushed into the reservoir and used by bacteria to degrade present hydrocarbons. This process produced ^{13}C depleted bicarbonate which was incorporated into the fracture-filling calcites. (Authors' abstract)

JI, Shen, DAOZHONG, Liu and **YIYING, Zhao**, 1989, A study of inclusion of the five quartz faults and the two deposits No. 325 and No. 326 in uranium ore field No. 322: J. Nanjing Univ. (Earth Sciences) 1989, no. 3, p. 58-68 (in Chinese, English abstract).

The U ore field No. 322 is located in the middle zone of the Zhuguangshan igneous body and is associated with five quartz-filled faults. The analysis of the inclusion composition in quartz and the results of microthermometry reveal that in the five quartz-filled faults, T are different and the anions are mainly HCO_3^-, Cl^-, and F^-. The cations are mainly Ca^{2+}, Na^+, and K^+. The two deposits in the ore field were formed ~200°C. The mineralizing fluid which contains Cl^- and SO_4^{2-} is acid, and also contained $UO_2(CO_3)_3^{4-}$. As T decreased and the pH changed and fluid interacted with the alkali-metasomatic rock, the U was precipitated and formed the deposits. (From authors' abstract by H.E.B.)

JOFFRION, L.L. and **EUBANK, P.T.**, 1989, Compressibility factors, densities and residual thermodynamic properties for methane-water mixtures: J. Chem. Eng. Data, v. 34, p. 215-220.

JOHAN, Z. and **OHNENSTETTER, M.**, 1989, Comprehensive model for genesis of chromite deposits within ophiolitic upper mantle (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-130. Authors at GIS BRGM-CNRS, Centre de Recherches sur la Synthèse et la Chimie des Minéraux, Orléans, France.

A detailed metallogenic study was made of chromite orebodies and their environment in Troodos, New Caledonia, and Oman ophiolitic mantle sequences. In particular, the mineralogy and geochemistry of chromitites and wall-dunites was investigated.

The paragenesis and chemistry of mineral phases included in chromitites are incompatible with crystallization of chromite from an essentially anhydrous magmatic liquid of basaltic composition, as is generally suggested.

Among the silicates, olivine, clinopyroxene, orthopyroxene, pargasite, a sodium phlogopite, nepheline, jadeite, and anothite were observed as inclusion in chromitite. This association comprises several phases (pargasite, Na-phlogopite, nepheline, jadeite) that cannot appear on or near the liquidus of basaltic magmas. Furthermore, the presence of hydroxyl-bearing minerals indicates a significant partial water pressure in the ore-forming system (OFS). All ferromagnesian phases are characterized by very high XMg ratio that is also incompatible with crystallization from a magmatic liquid of basaltic composition, and that cannot be entirely explained by reequilibration with chromite.

A strong tendency to form euhedral crystals is observed for included mineral phases. This indicates their crystallization from a fluid-rich OFS and is corroborated by the presence of fluid inclusions in several studied chromitites, pegmatitic wall-dunites, and great variation in the size of chromite crystals at the centimetric scale. The presence of pargasite, Na-phlogopite, nepheline, and jadeite indicates high Na-activity in the OFS. The T of crystallization of chromite is lower than maximum thermal stabilities of pargasite and Na-phlogopite (~1050°C). It is suggested that nepheline is a product of the incongruent melting of these two hydroxyl-bearing phases, induced by a rapid pressure decrease.

The latter led to the separation of a reducing fluid phase (presence of CH_4 and CO_2 in fluid inclusions), responsible for the precipitation of PGE-minerals, associated Ni-(Cu-Fe) alloys allowing the estimate of fO_2 at the T indicated above, and of chromite.

These results show that the origin of chromite orebodies within ophiolites is closely related to the transformation processes of the upper mantle induced by the presence of a fluid phase. (From authors' abstract by E.R.)

JOHANNES, Wilhelm, 1989, The importance of water for the formation of granite: Niedersächsische Akademie der Geowissenschaften, Publication Heft 1, Gesteinsfluide, p. 49-55.

JOHN, D.A., 1989a, Geologic setting, depths of emplacement, and regional distribution of fluid inclusions of the central Wasatch Mountains, Utah: Econ. Geol., v. 84, p. 386-409. Author at U.S. Geological Survey, MS 901, 345 Middlefield Rd., Menlo Park, CA 94025.

Nine mid-Tertiary calc-alkaline stocks, a subvolcanic porphyry system, and coeval volcanic rocks are exposed in a 45-km-long east-trending belt across the central Wasatch Mountains, Utah. The intrusions vary systematically from west to east in texture, style of emplacement, extent of contact metamorphism, hydrothermal alteration, and mineralization. P-depth estimates based on metamorphic mineral assemblages, stratigraphic reconstructions, and FI data indicate a regular variation in paleodepths ranging from about 11 km on the west to less than 1 km on the east. The data indicate that the central Wasatch Mountains have been tilted down to the east ~10° during the late Cenozoic. FI populations in igneous quartz also vary systematically with paleodepth; high-salinity (halite-saturated) FI are present in the eastern porphyry stocks and in the upper parts of the Alta and Clayton Peak stocks in the center of the belt but are absent in the deeper parts of the Alta and Clayton Peak stocks in the Little Cottonwood stock on the west side of the belt. In the Alta and Clayton Peak stocks, nearly planar high-paleosalinity horizons, presently dipping 15° to 20° east, separate rocks containing high-salinity FI (above the high-paleosalinity horizon) from those lacking such FI. Comparison of FI populations in igneous and vein quartz in the Alta and Clayton Peak stocks indicates that high-salinity fluids predated most of the vein-forming hydrothermal activity and provide the earliest record of fluids to circulate in these stocks. High-salinity fluids probably formed either by boiling of fluids released during the late stages of crystallization in the parts of the intrusions where P was <~1300 bars or by exsolution of immiscible high-salinity brines from the crystallizing magmas. Most hydrothermal mineralization associated with the intrusion, including Ag-Pb-Zn ores in the Park City district, are associated spatially with parts of the intrusions where high-salinity fluids were present. The major exception is the porphyry Mo system in the eastern part of the Little Cottonwood stock, which probably was at too great a depth (~7 km) to form high-salinity brines and is dominated by low-salinity CO_2-rich fluids. (Authors' abstract)

JOHN, D.A., 1989b, Evolution of hydrothermal fluids in the Park Premier stock, central Wasatch Mountains, Utah: Econ. Geol., v. 84, p. 879-902. Author at U.S. Geological Survey, MS 901, 345 Middlefield Rd., Menlo Park, CA 94025.

Park Premier is a low-grade Au-rich porphyry Cu system located about 3 km east of precious and base metal veins of the Park City district, Utah. Mineral compositions, fluid inclusion data, and inferred alteration reactions indicate that early alteration occurred at ≥600°C from hydrothermal fluids with unusually high salinities (≥82 wt % total salts) and low K/Na molar ratios (<0.25). These high-salinity brines probably formed by boiling of fluids released during crystallization of the microaplitic porphyries at high T (≥700°C) and low P (≤200 bars). Quartz + pyrite ± sericite veins and local alteration of high-T minerals to chlorite, sericite, calcite, and clay minerals occurred at much lower T (≤270°C) by the influx of dilute (0-3 eq. wt % NaCl), boiling meteoric(?) water.

Large areas of the igneous wall rocks of the microaplitic porphyries are altered to a variety of hydrolytic assemblages, including albite + sericite, sericite, kaolinite-dickite, pyrophyllite, and alunite (all + quartz ± pyrite). Albite + sericite, sericite, and local kaolinite-dickite alteration probably formed from chloride-dominated fluids derived from the microaplitic porphyries. Pyrophyllite and alunite alteration postdate all other types of alteration and formed along major northeast-trending fracture zones from fluids that were probably sulfate rich.

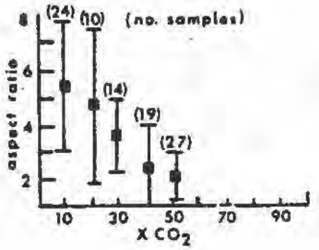
The hydrothermal system at Park Premier contains several features that are unusual in other well-described porphyry Cu systems but which may be common in Au-rich porphyry systems; they include: (1) early, extremely saline fluids that only migrated locally, (2) abundant magnetite, actinolite, and sodic plagioclase and relatively minor biotite, K feldspar, and sulfide minerals, (3) sparse quartz vein formation at <500°C, (4) little interaction of the microaplitic porphyries with dilute fluids until the intrusions cooled to ≤270°C, (5) early albitization of wall rock adjacent to the microaplitic porphyries, and (6) relatively high Au contents and high Au/Cu ratios of the microaplitic porphyries. These differences probably arose primarily from the very shallow depths of emplacement, small size of the intrusions, and low(?) sulfur contents of the magmas. (From author's abstract by E.R.)

JOHNSON, E.L. and **JENKINS, D.M.**, 1989a, Synthetic fluid inclusions in orthopyroxene: Inclusion morphology as a function of inclusion composition (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 34. Authors at Dept. Geol. Sci., State Univ. of New York at Binghamton, Binghamton, NY 13901.

Synthetically produced FI formed in orthopyroxene crystals via the breakdown of tremolite in the presence of fluids with varying XCO_2, show systematic morphological changes which correlate with fluid composition. Inclusion aspect ratios (length/width) show a systematic decrease with increasing XCO_2 content of the inclusion fluid (see figure below).

The inclusions are texturally P, tubular in shape, and are elongate parallel to the c-axis of the host pyroxene. The inclusion cavity is formed due to rapid growth along the c-axis of the host grain forming elongate "hopper" crystals which eventually grow together trapping draughts of the fluid. Low XCO_2 inclusions ($XCO_2 = 0.05$) have large aspect ratios (7:1-10:1), and where multiple inclusions occur in a single crystal, the inclusions are parallel but never fall on the same line within the grain. In contrast, inclusions with $XCO_2 = 0.3$-0.5 have smaller aspect ratios and they tend to form "trails" of up to four inclusions aligned along the c-axis of the host.

The compositional dependence is best explained by the increasing interfacial energy between the inclusion cavity and the fluid with increasing XCO_2. The situation, in terms of FI morphology, is analogous to Watson and Brenan's (1987, Earth Planet. Sci. Lett., 85) treatment of pore geometries in the presence of H_2O-CO_2 fluids. With increasing XCO_2, long narrow inclusion cavities become less stable and will tend to close off creating trails of inclusions with small aspect ratios.



FI morphologies may provide us with important clues as to the original fluid chemistry of texturally P inclusions whose compositions may have suffered post-entrapment alteration through leakage of diffusion processes. (Authors' abstract)

JOHNSON, E.L. and **JENKINS, D.M.**, 1989b, A technique for producing synthetic fluid inclusions in forsterite, enstatite and diopside (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A357. Authors at Dept. Geological Sciences and Environmental Studies, SUNY, Binghamton, NY 13901.

Synthetic H_2O-CO_2-NaCl fluid inclusions have been produced in forsterite, diopside, and enstatite during the spontaneous nucleation and growth of these phases via the reactions:

[1.1] $2TREM + 18H_2O = 4DIOP + 3FORST + 5Si(OH)_4 \cdot 2H_2O$

[1.2] $TREM + 3H_2O = 2DIOP + 3OPX + Si(OH)_4 \cdot 2H_2O$

The inclusions are large (10-40 μm), abundant and commonly of regular shape, making them ideal as standards for microthermic and spectroscopic analysis.

The procedure simply consists of loading ground tremolite plus the fluid mixture into a Pt or Pd/Ag capsule, sealing, and treating at the desired P-T conditions. Since the breakdown mechanism for reactions [1.1, 1.2] involves the incongruent dissolution of silica from tremolite, they are strongly dependent on the molality of SiO_2 in the fluid. In order to ensure satisfactory tremolite breakdown and host growth, therefore, large fluid/tremolite ratios (f/t by weight) are required. For P = 6-8 kbar and T = 850-950°C, the following f/t ratios appear to be optimal for inclusion formation: XCO_2 = (0-0.1) f/t = 10-25:1; XCO_2 = (0.1-0.35) f/t = 25-35:1; XCO_2 = (0.35-0.50) f/t = 30-60:1. Runs with $XCO_2 > 0.5$ produced little to no tremolite breakdown.

The advantages of this technique are (1) it provides a means of producing fluid inclusions of known composition in hosts other than quartz, and (2) inclusion formation is relatively slow, allowing ample time for the P-T-X(fluid) conditions of the run to equilibrate, thereby avoiding the potential problem of rapid fracture annealing during the heating process. The disadvantages are that the small grains produced can be difficult to work with, and the host-producing reactions are viable over a relatively narrow range of P-T-X(fluid) conditions.

Despite its limitations, this technique offers a relatively simple way to produce large primary fluid inclusions in hosts other than quartz. (Authors' abstract)

JOHNSON, J.W., 1987, Critical phenomena in hydrothermal systems: State, thermodynamic, transport, and electrostatic properties of H_2O in the critical region: PhD dissertation, Univ. Arizona.

JOLLIFF, B.L., **PAPIKE, J.J.** and **SHEARER, C.K.**, 1989, Inter- and intra-crystal REE variations in apatite from the Bob Ingersoll pegmatite, Black Hills, South Dakota: Geochimica Cosmochim. Acta, v. 53, p. 429-441. First author at Dept. Earth and Planet. Sci., Washington Univ., Campus Box 1169, St. Louis, MO 63130, USA.

Concentrations of rare earth elements (REE) have been measured on a suite of apatite crystals from an internally zoned granitic pegmatite enriched in Li, B, Be, F, Nb, Ta, Sn and U with a Cameca IMS 3f ion microprobe using energy filtering. Samples from several mineral assemblages show patchy individual crystal zoning with respect to the REE that is not mirrored by major element zoning. This indicates disequilibrium conditions on a small scale, consistent with rapid growth from a melt/fluid system that was either of locally heterogeneous melt structure, or in which the melt structure fluctuated rapidly as volatile rich minerals such as tourmaline crystallized. These effects may be coupled with non-ideal partitioning of REE in a heterogeneous mixture of melt, aqueous fluid and crystals. REE concentrations in apatite samples from the different pegmatite zones indicate a large variation in outer zones (10-500X chondrite), high concentrations (100-1000X chondrite) near the pegmatite core, and very low concentration in the core (2-20X chondrite). Patterns are flat to slightly inclined (Ce/Yb: 1 to 5), and most samples have positive Eu anomalies. The magnitude of positive Eu anomalies decreases with inward position in the pegmatite, possibly indicating a progressive increase in fO_2, and a sharp increase may be indicated by systematic Ce depletion in apatite from the pegmatite core. REE-specific volatile complexes may contribute to variations, including unusual kinks, observed in REE patterns of apatite from mineral assemblages in upper parts of the pegmatite. (From authors' abstract by E.R.)

JONES, B.K. and **LEVEILLE, R.A.**, 1989, Comparative elemental and oxygen isotope geochemistry of jasperoid in the northern Great Basin: Evidence for distinctive fluid evolution in gold-producing hydrothermal systems—A discussion. Econ. Geol., v. 84, p. 1705-1707.

See Holland et al., 1989, this volume. (E.R.)

JONES, H.D. and **KESLER, S.E.**, 1989, Evidence for methane-carbon dioxide vapor-rich inclusions in east Tennessee Mississippi Valley-type sphalerite (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359. Authors at Dept. Geological Sciences, Univ. Michigan, Ann Arbor, MI 48109.

Quadrupole fluid inclusions analyses of sphalerite from the Mascot-Jefferson City district show that a substantial proportion of CH_4 and CO_2 may reside in discrete vapor-rich inclusions, suggesting fluid immiscibility. Crushes of unheated samples have H_2O-dominated compositions and CH_4 in amounts as high as 2 mole %; other gases present in amounts less than 1 mole % include N_2-CO_2 > C_2H_6 > C_3H_8. Samples heated to 350°C before crushing had a total signal 10% that of unheated samples and were still H_2O-rich, but had almost twice as much CO_2 and CH_4, and up to twice as much $C_2H_6 + C_3H_8$ as unheated samples; this represents inclusions which would not have been analyzed by normal thermal decrepitation. Additional heating causes a further decrease in overall signal and a continued increase in CO_2 and CH_4 mole %.

Survival of inclusions to T far above those associated with district fluids can be accounted for by vapor-dominated inclusions with relatively flat-lying isochores. Dark inclusions with high internal reflection may be CH_4-rich, rather than solid inclusions. Analyses of small samples with greater amounts of these inclusions yield higher CH_4 than do samples with more two-phase aqueous-dominated inclusions. Thus, there may be two types of inclusions representing immiscible phases. Preliminary estimates suggest that most of the CH_4 and CO_2 in a bulk sample can be accounted for by these dark inclusions. If any vapor-rich inclusions were burst by thermal decrepitation in previous studies, calculations of partial P for the fluid phase would have been in error, and burial depths could be overestimated. (Authors' abstract)

JOYCE, D.B. and **HOLLOWAY, J.R.**, 1989, Experimental activity coefficients for H_2O in H_2O-CO_2-NaCl fluids (abst.): Eos, v. 70, p. 495-496.

JRAD, Lazare, TOURAY, J-C., BENY, Claire and **PERTHUISOT, Vincent**, 1989, Trapped and daughter minerals in brine inclusions; a micro-Raman and SEM investigation applied to quartz crystals from Triassic diapirs located in Northern Tunisia: C. R. Acad. Sci. Paris, t. 309, Série II, p. 43-48 (in French, with English abstract and abridged English version).

Combining optical characteristics and behaviour on heating with SEM and micro-Raman data results in the determination of the microscopic solids hosted by fluid inclusions. This approach has been applied to brine inclusions in quartz from Triassic diapirs. The results highlight possible transports of PO_4^{3-}, F^-, Ba^{2+} and Fe^{2+} by diapiric brines. (Authors' abstract)

Gives the Raman spectral peaks for the rhombohedral carbonates calcite, magnesite, dolomite and siderite. (E.R.)

JWA, Yong-Joo, 1989, Vein formation and mineralization of the Sambo Pb-Zn-Barite deposit, South Korea: Mining Geol., v. 39, no. 6, p. 383-391. Author at Geological Institute, Univ. Tokyo, Tokyo 113, Japan.

The Sambo Pb-Zn-Barite deposit belongs to a fissure filling vein type. The present study represents that the mineralized stages are classified into the four (I, II, III and IV). Major constituent minerals of each stage are as follows: quartz and sulfides (stage I), barite (stage II), quartz and sulfides (stage III) and quartz (stage IV).

The ranges of Th of fluid inclusions for stages I and III are very similar (90° to 300°C for stage I and 120° to 310°C for stage III), while the range for stage II (110° to 260°C) is slightly lower than those for stages I and III. However, the salinity for stage II (8.7 to 11.8 wt % NaCl eq.) is higher than those for stage I (1.1 to 5.1 wt % NaCl eq.) and stage III (2.3 to 5.7 wt % NaCl eq.). The higher salinity for stage II (barite-forming stage) suggests the possibility of mixing of original fluid with high saline, Ba-rich solution (probably connate water origin). And the mixing may be responsible for the slightly lower range of Th for stage II than those for stages I and III. Stage IV, the latest stage, shows the lowest range of Th (110° to 170°C). (Author's abstract)

KACANDES, G.H. and **GRANDSTAFF, D.E.**, 1989, Differences between geothermal and experimentally derived fluids: How well do hydrothermal experiments model the composition of geothermal reservoir fluids?:

Geochim. Cosmochim. Acta, v. 53, p. 343-358. First author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16801.

Fluid parameters from a diverse set of dilute water/rock experiments (80°-300°C) were compared with reservoir data from several geothermal fields. The comparisons show that experiments of this type can reproduce many properties of geothermal reservoir fluids. Compositional parameters for most species in experimentally derived fluids are T dependent but are relatively independent of rock type, initial fluid composition, and water/rock mass ratio. At lower T ($\leq$250°C), many experimental parameter-T trends agree with geothermal trends. However, at higher T ($\geq$250°C), the geothermal fluids have calculated high-T pH values 1 to 2 pH units lower than do the experimentally derived fluids. This produces a consistent offset between values of experimental and natural cation/proton activity ratios. Two possible experimental reasons for offsets are pervasive metastable mineral formation in experiments; and absence, in experiments, of the equivalent of a magmatic or metamorphic gas input. Results from current experiments suggest that, while metastability may be partially responsible for offsets, observed geothermal fluid parameters can be duplicated by addition of CO_2. Furthermore, maintenance of high fCO_2, low pH conditions requires a CO_2 flux. Finally, in geothermal fields, addition of exotic CO_2 or other acid gases during upflow or sampling of wet steam discharges may also contribute to such offsets by producing lower than actual reservoir pH values. Thus the offsets could suggest that some geothermal fluid pH values are more basic than commonly calculated and closer to those pH values produced during dilute water/rock experiments. (Authors' abstract)

KADIS, A.A. and **SHILOBREEVA, S.N.**, 1989, Carbon and its volatile compounds in silicate melts and crystals: Mangle [Mantle?] magma outgassing problems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-144.

KALOGEROPOULOS, E.I., KILIAS, S.P., BITZIOS, D.C., NICOLAOU, M. and **BOTH, R.A.**, 1989, Genesis of the Olympias carbonate-hosted Pb-Zn (Au,Ag) sulfide ore deposit, eastern Chalkidiki Peninsula, northern Greece: Econ. Geol., v. 84, p. 1210-1234. First author at Inst. Geology and Mineral Exploration (IGME), 70 Mesoghion St., Athens 115 27, Greece.

The geologic setting of the ores consists predominantly of marbles, biotite-hornblende gneisses, and amphibolites. These rocks have been regionally deformed and metamorphosed to amphibolite facies. This event in the Kerdilia Formation seems to have lasted until the early Tertiary and culminated in anatexis and calc-alkaline magmatism.

The Olympias deposit is generally stratabound or fracture controlled and in places stratiform. However, in all cases a chemical reaction front in the marble is present. The Olympias deposit occurs in undeformed and deformed varieties. The main ore mineral paragenesis at Olympias regardless of deformation is pyrite, galena, sphalerite, and arsenopyrite with quartz, calcite, and rhodochrosite as gangue minerals.

Lead isotope compositions of deformed or undeformed ore galenas indicate a crustal source and are homogeneous and identical with K feldspar leads from the Stratoni granodiorite and other Tertiary Greek orogenic granites. These data suggest that the source of the ore leads should be sought in the source of the magmas. Moreover, the crustal affinity and homogeneity of the studied lead isotopes are in agreement with the crustal component contributing to the Tertiary granite formation, even though leaching of lead from crustal rocks cannot be completely disregarded.

The narrow range of sulfur isotope ratios in all the sulfides, and their proximity to 0‰, combined with the relatively limited occurrence of sulfates (e.g., gypsum) at Madem Lakos, may suggest the combined effects of high reduced/oxidized sulfur species ratios, relatively high T, and small $\delta^{34}S(\text{initial})-\delta^{34}S(H_2S)$ values, thus suggesting an igneous origin for the sulfur.

Fluid inclusion studies in ore-related quartz from Olympias have shown that both deformed and undeformed ore varieties have formed by the same H_2O-dominated CO_2-bearing fluids of low to medium salinity, at 300° to 400°C, and P of 300 to 800 bars. Preliminary fluid inclusion data from Madem Lakos show higher Th $\leq$480°C and complex salt ($NaCl-KCl-CaCl_2$) contents.

Oxygen isotope analyses of ore-related quartz and calcites combined with thermometric data from fluid inclusions and arsenopyrite composition suggest that the mineralizing fluids were of either magmatic or metamorphic derivation with late involvement of meteoric waters. Oxygen and carbon isotope analyses from upper marble-, host marble- to ore-related calcites show a depletion primarily of oxygen indicating an isotopic exchange with infiltrating H_2O-dominated mineralizing fluids. This depletion is correlatable with the degree of hydrothermal alteration expressed by enrichment in the ore host marble compared with the upper marble horizon.

Bulk ore compositions show a similarity of the Olympias with the skarn replacement ore type, rather than with the sediment-hosted or the volcanogenic Pb-Zn types. These data, together with data from mineralogical and fluid inclusion studies, suggest that Olympias is predominantly a distal (replacement), whereas Madem Lakos is a proximal (skarn) phase of a skarn replacement ore system.

Therefore, our preferred interpretation is that both deformed and undeformed ore varieties at the Olympias (also presumably at Madem Lakos) deposit formed during the same Tertiary skarn replacement metallogenetic event from fluids of primarily magmatic derivation through reaction with the host marbles at low P (300-800 bars) and relatively high T (300°-400°C). (From authors' abstract by E.R.)

KALYUZHNYI, V.A., 1988, Essential results and development perspectives of the science on mineral-forming fluids (problems of thermobarometry and geochemistry of ore-forming fluids), *in* V.A. Kalyuzhnyi et al. (eds.), Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press, p. 3-10 (in Russian).

The joint use of traditional and fluid inclusion methods was especially fruitful for prospecting for W, Mo, topaz-morion and mica pegmatites, Sn, polymetals and Au. In the Transbaikalia granitoids the heavy mineral and thermobarometric prospecting indicated W ores and barren areas. Detailed paleotemperature mapping was especially useful for Au prospecting. The author summarizes various Soviet fluid inclusion works in metamorphic, volcanic and ore-bearing minerals. He indicates, however, that these works are based on statistical results, i.e., on methods yielding average data from numerous inclusions like water leachates, decrepitation, bulk gas analysis, etc. More important results may be obtained by thorough studies of individual inclusions. This way, one can detect peculiarities of T regime, especially the existence of T stages; this was not pointed out in many papers discussing this problem at various deposits. The most important results can be listed as follows: (1) extension of the T ranges of the hydrothermal and magmatic mineral formation when compared with earlier opinions; (2) evidence that practically all mineral bodies formed at low to moderate depths and crystallized from boiling hydrothermal solutions; (3) absence of evidences of the common occurrence in nature of pneumatolytic conditions; (4) evidence that CO_2 is the most common volatile at large depths and evidence of its mantle source; (5) determination of the P-T conditions and fluids (CO_2, N_2 and CH_4) of metamorphism and anatexis; (6) statement of a special regime of H_2 in mineral-forming processes and its practical absence in inclusions; (7) finding of the periodic changes of pH during hydrothermal post-magmatic crystallization; and (8) method of the H_2O content calculation in magmatic melt during its crystallization. (A.K.)

KANAKIN, S.V., REIF, F.G. and FIRSOV, A.P., 1988, Procedure for electron-probe analysis of melt inclusions in minerals of acidic rocks: Geoligiya i Geofizika, v. 29, no. 10, p. 75-80 (in Russian; translated in Soviet Geol. Geophys., v. 29, no. 10. p. 68-72).

The insufficient reliability of results of standard electron-probe microanalysis of melt inclusions in minerals of silicic rocks is shown, which is connected with instability of the object of analysis (aluminosilicate glass) under the electron probe. For the instruments of the MS-46 type, a method of improved analysis is suggested, especially in relation to sodium. The method's possibilities are illustrated by analysis of two types of melt inclusions. (Authors' abstract)

KANAZAWA, K., TAKENOUCHI, S. and MARIKO, T., 1989, Chemical analysis of fluid inclusion—An example of the Takatori mine (abst.): Min. Geol., v. 39, p. 55-56 (in Japanese, translated by S. Taguchi). First author at Fac. of Sci. Tech., Waseda Univ.

Chemical analysis of fluid inclusions was carried out by ion chromatography. Samples were quartz from one of the Takatori Sn-W ore deposits in Japan, including 15 massive quartz samples and eight druse quartz samples. Na, K, Ca, Mg, Mn, Zn and Li were detected in all samples, and NH_4 in some. Anions Cl, F and SO_4 were detected in all samples, and Br and NO_3 from some. The amounts of Na and Cl are several 10,000 ppm [i.e., xo,ooo ppm?], and K, F and SO_4 several 1000 ppm [xooo ppm]. Solutes are generally high in fluid inclusions from massive quartz. On a Na-K-Ca diagram, fluid from massive quartz is relatively high in Ca (up to 20%). On the other hand, fluid in druse quartz is rich in Na (more than 95%). Moreover, on a diagram of Cl-F-SO_4, fluid from massive quartz is Cl-F composition (F = up to 60%) but that from druse quartz is rich in Cl (more than 80%). (Authors' abstract)

KANEDA, H. and TAKENOUCHI, S., 1989, Geological significance of gases in fluid inclusions from Korean gold-silver deposits (abst.): Min. Geol., v. 39, p. 68-69 (in Japanese, translated by S. Taguchi). Authors at Univ. Tokyo.

Gas contents of fluid inclusions in quartz from some Au-Ag deposits in the southern part of the Korean Peninsula were obtained. The results are H_2O = 5000-10,000 µmole, CO_2 = 20-2000 µmole, CH_4 = 20-300 µmole, and N_2 = 0-850 µmole per 1 g of quartz, respectively. On a diagram of H_2O - (CO_2 + CH_4) - N_2, gas contents of most deposits plot at <10 mol % CO_2 + CH_4, and at <3 mol % N_2. Based on the analytical results, calculation of fO_2 in the H_2O-CO_2-CH_4 system indicates that fO_2 values of the deposits follow the pyrite-pyrrhotite-magnetite buffer line (log fO_2 = -35 to -33 at 300 and 350°C, respectively), in most cases. In addition, the electrum becomes Au-rich, with increase of fO_2 in solution. (Authors' abstract)

KARPUKHINA, V.S. and BARANOV, E.N., 1988, Evidence of boiling in hydrothermal solutions at copper-sulfide deposits of the Verkhneural'skiy ore region (S. Urals): Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 16-17 (in Russian). Authors at Inst. Geochem. and Anal. Chem., Moscow, U.S.S.R.

Sulfide bodies of Verkhneural'skiy ore region are of hydrothermal-sedimentary origin. The conduits of paleohydrotherms are distinctly recognizable, especially as linear zones of high paleotemperatures (300°C). Inclusion studies showed the hydrothermal fluids to be K, Na or K-Na types, 3-11 wt % NaCl eq.; gas phase consists mainly of CO_2. Isotope analysis of hydrogen and oxygen of sericite from metasomatites indicates that seawater prevailed in the fluid composition. The following signs of fluid heterogenization were found in the conduit zones: together with prevailing two-phase G/L inclusions, either three-phase LH_2O + LCO_2 + GCO_2 inclusions or LCO_2 + GCO_2 inclusions occur. At the Uzel'ga deposit the width of the zone of heterogenization reaches 300 m, its depth up to 500 m, narrowing at deeper levels, maximum Th 340°C, P 1.2-0.5 kbar. Boiling occurred also at Zapadno-Ozernoe deposit (Th up to 320°C, P 0.8-0.6 kbar), at Chebach'ye deposit (up to 370°C, 0.7-0.5 kbar), whereas at the deposits Talga and Molodyozhnoe boiling was not recognized (Th up to 330°C). (From the authors' abstract, translated by A.K.)

KATZ, Amitai and KOLONDY, Nancy, 1989, Hypersaline brine diagenesis and evolution in the Dead Sea-Lake Lisan system (Israel): Geochimica Cosmochim. Acta, v. 53, p. 59-67. First author at Dept. Geol., Inst. Earth Sci., The Hebrew Univ., Jerusalem, Israel.

Water soluble salts were extracted from 57 aragonite and detrital laminae, sampled for the Pleistocene Lake Lisan sediments. The solutions and solids were analyzed for Ca, Mg, Na, K, Sr, Cl, SO_4 and bicarbonate. Average Na/Cl, Mg/Ca, Sr/Ca, Mg/Cl, Ca/Cl, Sr/Cl, K/Cl, K/Na, and K/Mg ratios, calculated for seven stratigraphic elevations in the Lisan column, indicate that the Dead Sea Rift sediment/brine system has remained practically closed for 70000 years. The soluble salts reflect both the hydrologic evolution of the lake as well as diagenetic process. Mg/Ca ratios systematically decease in younger sediments, and this decline is accompanied by a 1.5-4 fold Sr enrichment in aragonite solubles relative to salts extracted from detrital laminae.

The major process responsible for these observations is dolomitization of Sr-rich aragonite by interstitial brine. Diagenesis was triggered by slow desiccation of the lake's sediments after the Lisan waters started to recede due to a change in climate. Very sharp chemical gradients, which developed in the sediments after deposition, have been preserved because further diagenesis was quenched by the advancing dry-out. H_2O-loss by evaporation induced diffusional migration of Na and Cl from aragonite laminae into adjacent detrital layers. This lowered the Na/Cl ratio in the aragonite and raised it in the detritus relative to the initial (Dead Sea) Na/Cl ratio of 0.26.

The early Lisan brine was similar in its chemical composition and total salinity to that of the present Dead Sea. (Authors' abstract)

KAUL, I.K., RAO, C.N. and SANYAL, T., 1989, A new technique for the determination of homogenization temperatures of fluid inclusions: J. Geol. Soc. India, v. 34, p. 333-337. Authors at Dept. Geology and Geophysics, I.I.T., Kharagpur 721 302.

A new technique to determine Th of fluid inclusions is described. The technique is based on the principle of optical density and involves no ambiguity in recording Th, unlike in the standard heating stage method where because of problems of visual clarity of liquid phase disappearance, accurate measurement of Th becomes difficult and unreliable. A comparison of the two methods shows that the present technique gives somewhat higher values than those based on heating stage method. (Authors' abstract)

KELLEY, D.S., 1989, High temperature, high salinity fluid inclusions in plagiogranites from Cyprus (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 35. Author at Dept. Geol., Dalhouise Univ., Halifax, Nova Scotia, Canada B3H 3J5.

Preliminary results from microthermometric analyses of quartz-hosted FI in fresh and epidotized plagiogranites from Cyprus, indicate that generation of brine-rich fluids (>40-50 wt % NaCl) at >400-500°C, is pervasive throughout many of the plagiogranitic bodies. The P(?) and S brine-rich inclusions, which commonly contain hematite(?) dms, have Th at Tm NaCl at 400-500°C and Th L-V(L) at 300-400°C. Quartz-hosted, vapor- and liquid-dominated, low-salinity (2-6 wt % NaCl) S FI are ubiquitous in all plagiogranite samples studied. Th of the low-salinity inclusions, at uncorrected T of 300-400°C, rarely occurs in the vapor phase.

FI homogenization by Tm NaCl indicates that brine-rich fluids were trapped in the absence of a vapor phase at 400-500°C. In addition, the lack of any halite casts in the quartz-hosts suggests that the fluids were not saturated with respect to NaCl at the time of entrapment. Possible models for generation of such highly saline brines may include two-phase separation of either seawater- or magmatically-derived fluids with subsequent migration of the vapor out of the system.

Low salinity, quartz-hosted S FI in the plagiogranites and in hydrothermal quartz-feldspar veins, which crosscut the plagiogranites, indicate later circulation of low salinity (2-6 wt % NaCl) fluids at 300°C. (Author's abstract)

KELLEY, D.S. and ROBINSON, P.T., 1989, Circulation of highly-saline fluids (46-56 wt % NaCl) at temperatures >400-500°C in the upper plutonic sequence, Troodos ophiolite, Cyprus (abst.): Eos, v. 70, p. 1396. First author at Geology Dept., Dalhousie Univ., Halifax, N.S. B3H 3J5, Canada.

Microthermometric analyses of quartz- and epidote-hosted FI in fresh and epidotized plagiogranites from the Troodos ophiolite, Cyprus, indicate the development of a deep-seated, brine-dominated hydrothermal system in the upper level plutonic sequence. Quartz-hosted, highly-saline (46-56 wt % NaCl eq.), Fe-rich S FI record fracturing in the upper level plutonics at >400-500°C. Homogenization of the high-T I by halite dissolution at 400-500°C indicates the fluids were entrapped in the absence of a vapor phase. The highly-saline I are interpreted to have formed as a result of two-phase separation at >400-500°C of seawater or an exsolved magmatic phase. Migration of the fluids along microfracture networks near the margins of the plagiogranite bodies, and stratification of the phase separated fluids, resulted in segregation of the vapor and brine phases and preferential entrapment of the high-salinity I at depth. Subsequent fracturing, allowing ingress of hydrothermal seawater, resulted in formation of hydrous mineral phases and entrapment of low-T (200-300°C), low-salinity (<1-7 wt % NaCl) fluids. (Authors' abstract)

KENNEDY, B.M., TRUESDELL, A.H. and HEARN, E.H., 1989, Helium isotopes and hydrothermal fluid chemistry (abst.): Eos, v. 70, p. 1378. First author at Dept. Physics, Univ. California, Berkeley, CA 94720.

High $^3He/^4He$ ratios at Yellowstone reflect the presence of magmatic He derived from a cooling batholith at a depth of -5 km (1,2). In thermal springs, ratio variations are produced by addition of radiogenic He from crustal aquifer rocks (2). Within individual geyser basins variations can be large, are spatially correlated, and occur over lateral distances short compared to the depth to the batholith. Thus, within individual basins, the variations may not reflect differences in the flux of the magmatic component from the batholith.

Detailed study of He isotopes and H_2O chemistry in Lower and Shoshone Geyser basins (3,4) has led to a model in which surface $^3He/^4He$ ratios depend on the extent of deep boiling and/or dilution. The observed positive correlation of $^3He/^4He$ ratios and HCO_3 suggests that both CO_2 and ^3He are lost when deep boiling and phase separation occur and retained when cooling is by dilution. CO_2 retained in the liquid is converted to HCO_3 by reaction with rocks, and unboiled fluids high in total He retain high $^3He/^4He$ ratios unaffected by addition of radiogenic 4He from rock. Boiled waters low in both CO_2 and ^3He produce spring fluids with low HCO_3 and low $^3He/^4He$ ratios.

1. Craig et al., 1978, GRL 5, 897-900.
2. Kennedy et al., 1985, GCA 49, 1251-1261.

3. Kennedy et al., 1987, JGR 92, 12477-12489.
4. Hearn et al., 1989, submitted to GCA. (Authors' abstract)

KEPPLER, Hans, 1989, A new method for the generation of N_2-containing fluids in high-pressure experiments: Eur. J. Mineral., v. 1, p. 135-137.

KEPPLER, H. and **WYLLIE, P.J.,** 1989, Partitioning of Mo, W, U, Cu, and Sn between granitic melt and fluid phase (abst.): Eos, v. 70, p. 1403.

KERKHOF, A.M. van den, 1989a, The system CO_2-CH_4-N_2 in fluid inclusions: The determination of the molar volume by the application of isochoric phase diagrams (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 66. Author at Inst. Earth Sci., Free Univ., De Boelelaan 1085, 1081 HV Amsterdam (NL). (Name given as "Fons M. Van Den Kerkhov" in original.)

Analysis of FI by Raman microspectroscopy and phase behavior shows that many nonaqueous fluids in metamorphic rocks consist of *mixtures* between CO_2, CH_4 and N_2. The interpretation of these fluids in respect to molar volume and trapping PT conditions is more difficult than for pure compositions. Miscalculations on fluid densities can be easily made if pure fluids are assumed.

The *molar volume* (V) is the most important quantity to be determined for FI in order to calculate the trapping P. Until now, V could only be determined indirectly, namely from (1) phase transition T between -160 and +35°C (microthermometry), (2) compositions (Raman analysis), and (3) phase diagrams. Accurate knowledge on multicomponent phase relations is therefore indispensable for a proper interpretation of FI. The binary system CO_2-CH_4, CO_2-N_2 and CH_4-N_2 could be established for the full range of compositions (van den Kerkhof, PhD thesis, Free Univ., 1988); the ternary system could be established in a semiquantitative way. Fortunately, many fluids were found to represent binary mixtures by approximation.

FI represent "*isochoric*" systems (constant volume). However, phase diagrams are traditionally drawn as isobaric (TX)-sections (constant P) (Burruss, 1981, MAC Shortcourse Handbook 6, Fig. 1a). In spite of the advantage of showing compositions of the individual phases, their use for FI studies is very limited. Diagrams showing correlations between molar volume (V), temperature (T) and composition (X) are more convenient, e.g., (1) isochoric PT diagrams, and (2) isothermal VX diagrams. They could be established for the binary system CO_2-CH_4 (Fig. 1b) and CO_2-N_2 from assembled literature and additional experimental data. Until recently, the shape of these diagrams was not known for larger compositional and volumetric ranges. All possible types of phase transitions observed in CO_2-CH_4-N_2 inclusions can now be explained in respect to composition and molar volume. Consequently, interpretations on rock-forming PT conditions from FI data have become more reliable. (Author's abstract)

See also Fluid Inclusion Research, v. 20, p. 389-390. (E.R.)

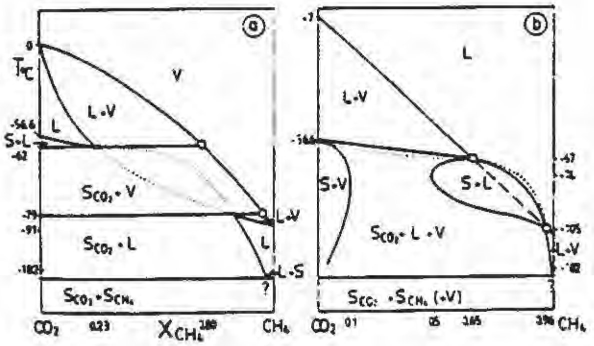


Fig.1.- The system CO_2-CH_4 presented as a) isobaric and b) isochoric TX-diagram. The pressure and the molar volume of the examples are about 35 bar and 50 cm^3/mole respectively.

KERKHOF, A.M. van den, 1989b, Fluid inclusions in the system CO_2-CH_4-N_2: A systematic classification (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 55-56. Author at Inst. Earth Sci., Free Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

Water-free inclusions containing CO_2, CH_4 and N_2 and their mixtures occur in a number of geological environments, notably in lower crustal and upper mantle rocks. The molar volume of FI is the key parameter for the calculation of the trapping PT conditions and can be determined from phase transitions in the T range between -160 and +35°C ("microthermometry"). The phase behavior reflects both molar volume and composition of the fluid. The complexity of observed phase transitions imposes a re-evaluation of commonly accepted terminology for melting, homogenization and sublimation phenomena.

Based on theoretical considerations, the study of many natural samples and experimental data, a unified classification system is proposed which covers in principle any composition and density in the CO_2-CH_4-N_2 system. Two major types, H (for homogenization) and S (for sublimation) are determined for the final phase transition observed at increasing T. Each of the H or S inclusions may show a succession of phase transitions (Table 1), defining 9 sub-types (H1 and S1 to S4).

Inclusions belonging to each sub-type have been actually observed in natural samples. For binary mixtures (CO_2-CH_4 and CO_2-N_2), it is now possible to calculate the molar volume of the inclusion, knowing the T of the phase transition *and* the composition. (Author's abstract)

Table 1.

The final multi-phase assemblage upon warming = L+V (H-type)

	S+L	→	S+L+V	→	S+L or S+V	→	S+L+V	→	L+V	→	L or V
H1									...	ThL/V	...
H2							...	Tm	...	ThL/V	...
H3						TiV	...	Tm	...	ThL/V	...
H4			...	Ths	...	TiV	...	Tm	...	ThL/(V)	...
H5	...	Ti	...	Ths	...	TiV	...	Tm	...	ThL/(V)	...

The final multi-phase assemblage upon warming = S+L or S+V (S-type)

		→	S+L+V	→	S+L	→	S+L+V	→	S+L or S+V	→	L or V
S1									...	Ts	...
S2							...	ThsL/V	...	Ts	...
S3					...	TiL	...	ThsL	...	Ts	....
S4			...	ThsL	...	TiL	...	ThsL	...	Ts	...

Metastable (S-type)

	L+V	→	L or V
S1 to S4	... ThmL/V ...		

KERKHOF, A.M., van den and TOURET, J.L.R., 1989, Systematic classification for gaseous inclusions in the CO_2-CH_4-N_2 system (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-278-279. Authors at Free Univ., Amsterdam, The Netherlands. [Paper not presented at Congress. E.R.]

Water-free inclusions containing CO_2, CH_4 and N_2 and their mixtures occur in a number of geological environments, notably in lower crustal and upper mantle rocks. Only pure CO_2 (maximum Th +31°C) may be biphased showing L(iquid) and V(apor) at room T. All other compositions appear to be gaseous as they contain a single supercritical fluid (F). Therefore, they cannot be distinguished from open, empty cavities. But upon cooling, they show complicated phase transitions to liquid (L) and/or solid (S) in the range +31 to -180°C. At low T, inclusions containing CO_2-CH_4-N_2 fluids present a number of unusual features [such as:] the possible transition $S \rightarrow F$ (liquid *or* vapor) upon warming ("sublimation"), without the occurrence of a three-phase equilibrium (S+L+V); successive homogenization in the same inclusion at intermediate (+31/-60°C: $L+V \rightarrow F$) than at low T (below -70°C: $S+L+V \rightarrow S+F$); existence of metastable homogenization.

Binary mixtures (CO_2-N_2 and CO_2-CH_4) show small variations in the fluid melting T and large decrease in the Th compared to pure CO_2. Therefore, low density mixtures can be easily confused with high density CO_2. In practice, the composition cannot be derived from phase transition T and it needs to be measured directly, notably by Laser excited micro Raman analysis. Based on theoretical considerations, the study of many natural samples and experimental data, a unified classification system is proposed which can cover in principle any composition and density in the CO_2-CH_4-N_2 system (van den Kerkhof, 1988, PhD thesis, Vrije Univ., Amsterdam): (1) Two major types, H (for homogenization) and S (for sublimation) are determined from the final phase transition observed at rising T: L+V → F and S+V or S+L → F, respectively (where F denotes L or V). (2) Each of the H or S inclusions may show a succession of phase transitions, defining nine subtypes (H1 to H5 and S1 to S4) according to the table. Type H3 and H1 inclusions are characteristic for CO_2-rich and CO_2-poor fluids, respectively. H2-type inclusions are unique for CH_4-rich fluids; H4-type inclusions are unique for N_2-rich compositions. S2-type fluid inclusions are common for higher N_2-contents and lower molar volumes, but they may occur for both CO_2-N_2 and CO_2-CH_4 fluids for molar volumes <65 cm^3/mole. H5-type inclusions (all of CO_2-CH_4 composition) are extremely rare and can be seen as a special type of H4; S3- and S4-type inclusions represent CO_2-N_2 fluids of very low molar volume (~40 cm^3/mole). S1-type inclusions are mostly of very high molar volume, but sometimes extremely low molar volume.

Inclusions belonging to each subtype have been actually observed in natural samples. For binary mixtures (CO_2-CH_4 and CO_2-N_2), it is now possible to calculate the molar volume of the inclusions, knowing the T of the phase transition *and* the composition.

KESLER, S.E., 1989a, Tectonic setting and origin of Mississippi Valley-type deposits in the Appalachian orogen (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-179.

KESLER, S.E., 1989b, Subvolcanic hydrothermal systems in the continental crust (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 151. Author at Dept. Geological Sciences, Univ. Michigan, Ann Arbor, MI 48109.

Hydrothermal systems are associated with most subvolcanic environments in the upper 5 km of the continental crust. According to the fluid inclusion record found in ore deposits that were formed by these systems, they can be divided into two groups. *Simple* systems consist essentially of low to moderate salinity, chloride-bearing H_2O with a low K/Na ratio, which boils as it rises, releasing vapors that condense in the top of the system. These systems rarely exceed 300°C, occupy tens to hundreds of cubic km, and appear to consist dominantly of meteoric H_2O. Low salinity (>1% NaCl) waters in these systems form Au-Ag-As-Sb or W-Sn veins (depending on relative abundances of H_2S and CO_2), higher salinity (up to 30% NaCl) waters form Pb-Zn-Cu-Ag veins, and the vapors mix with overlying groundwater to form Hg-Sb deposits. *Complex* systems include highly saline, chloride-rich brine with a high K/Na ratio and coexisting vapor. These systems have T in the 300° to 800°C range, occupy volumes of only a few cubic km, and appear to have been derived largely from cogenetic magma. The saline brines form porphyry Cu-Mo-Au and skarn Cu-Pb-Zn-Ag deposits, whereas the vapors mix with groundwater to form acid-sulfate Au-Ag deposits. Complex systems are commonly enclosed with a larger, peripheral simple system, although all simple systems are not known to be cored by complex systems.

Although deeper parts of all systems are hotter than shallower parts, both types of hydrothermal systems can form at similar crustal depths, depending on the position and crystallization history of genetically related magma. Granitic batholiths that are confined to larger, deeper chambers commonly serve as sources of heat to drive long-lived simple systems. Granodioritic stocks, which reach higher levels in the crust and release water and gases more rapidly and violently, create shorter-lived complex systems that form chemical and thermal perturbations in the larger scale, simple systems. Systems of both types tend to remove their upper parts explosively, with hydrothermal explosions associated with simple systems extending to shallower depths than magmatic(?) explosions associated with complex systems. The main uncertainty in the overall evolution of continental hydrothermal systems is the chemical contribution made to these systems by magmas. (Authors' abstract)

KESLER, S.E., 1989c, Evolution of Mississippi Valley-type (MVT) brines in Lower Ordovician carbonate rocks of the Appalachian Orogen (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A8. Author at Dept. Geological Sciences, Univ. Michigan, Ann Arbor, MI 48109.

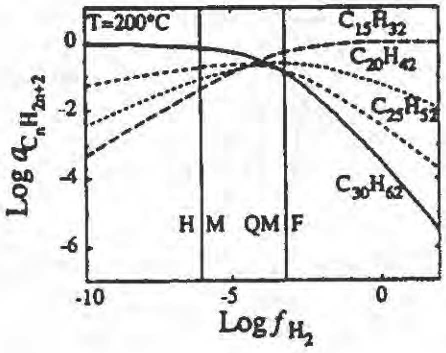
Two types of MVT deposits are hosted by Lower Ordovician carbonate rocks in the Appalachian Orogen. The best known type, which consists almost entirely of sphalerite and sparry dolomite, is found from Georgia to Newfoundland and is commonly referred to as Appalachian-type. A less abundant type, which consists largely of fluorite and barite with limited sphalerite and sparry dolomite, is largest and most widespread in the southern part of the Appalachians. Paragenetic observations and strontium isotopic and fluid inclusion compositions for these two MVT deposit types in the East Tennessee ore field indicate that fluorite-barite mineralization formed first from relatively cool, Ca-rich brines (Ca:Na=1), whereas sphalerite-rich mineralization formed later from warmer, Na-Ca brines (Ca:Na=0.1 to 0.6). Geologic relations suggest that these brines were derived from the southeast, in the area of the Middle Ordovician Sevier foreland shale basin, and that membrane filtration enriched the early brines in Ca. Constraints imposed by fluorite solubility suggest further that the volume of connate water in the Sevier basin would have been adequate to deposit the estimated fluorite reserves of the ore field, but that later, sphalerite-depositing brines probably represent recycled meteoric water from the Sevier basin or connate brines from underlying (Cambrian) shales. The remarkable similarity in S and Pb isotopic compositions for Lower Ordovician-hosted MVT deposits in Tennessee, Pennsylvania and Newfoundland, suggests that this fluid evolution applies to all Appalachian-type MVT deposits. (Author's abstract)

KESLER, S.E., GESINK, J.A. and HAYNES, F.M., 1989, Evolution of mineralizing brines in the east Tennessee Mississippi Valley-type ore field: Geology, v. 17, p. 466-469. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

The east Tennessee Mississippi Valley-type (MVT) ore field contains barite-fluorite and sphalerite deposits in a continuous paleoaquifer consisting of breccia zones in the Upper Cambrian-Lower Ordovician Knox Group. Paragenetic observations and FI compositions in these deposits indicate that the Knox paleoaquifer was invaded first by Ca-rich brines (Ca:Na about 1) that deposited fluorite and barite, and later by Na-Ca brines (Ca:Na = 0.1 to 0.5) that deposited sphalerite. Geologic relations indicate that these brines were derived from the southeast, in the area of the Middle Ordovician Sevier foreland shale basin, and that membrane filtration could have played a role in enriching the early brines in Ca. Constraints imposed by fluorite solubility indicate further that all original connate water in the Sevier basin was required to deposit the estimated fluorite reserves of the ore field. Thus, the later, sphalerite-depositing brines represent recycled meteoric water for the Sevier basin or connate brines from underlying (Cambrian) shales. (Authors' abstract)

KETTLER, R.M. and MEYERS, P.A., 1989, Hydrocarbon speciation in hydrothermal systems: Redox controlled? (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A48. First author at Dept. Geology, Univ. Nebraska, Lincoln, NE 68588.

C_{15+} hydrocarbon fractions obtained from modern and fossil hydrothermal systems often exhibit depletion of short chain (C_{15}-C_{20}) n-alkanes which is ascribed to dissolution of hydrocarbons as molecular species (water washing). It is also possible that the hydrocarbon speciation observed reflects metastable equilibria in an oxidizing hydrothermal system. To model the latter we have estimated thermochemical data for some n-alkane hydrocarbons and calculated the distribution of hydrocarbon species within an organic phase, as a function of the oxidation state. *Estimates* of $\Delta H^{\circ}f_{,298}$, S°_{298}, and Cp at 300-1500 K for n-alkanes from n-$C_{15}H_{32}$ through n-$C_{30}H_{62}$ were made by addition of group properties using published group values. Free energy data were calculated for the ideal gas stage and converted to condensed states using published vapor P data. *Distribution of hydrocarbon species* within an ideal solution indicates that under reducing conditions (quartz-magnetite-fayalite) short chain n-alkanes are stable relative to longer chain hydrocarbons. If equilibrium with CO_2 is overstepped, longer chain hydrocarbons become stable under more oxidizing conditions (hematite-magnetite). The depletion of shorter chain n-alkanes observed in hydrothermal systems is consistent with an approach to metastable equilibrium. C_{15+} n-alkane distributions observed in the Carlin-type gold deposit at Alligator Ridge, Nevada, and in some seafloor hydrothermal systems exhibit depletion of shorter chain n-alkanes, consistent with such carbon-conservative oxidation. (Authors' abstract)



KHALIL, M.A.K. and **RASMUSSEN, R.A.,** 1989, Temporal variations of trace gases in ice cores, *in* H. Oeschger and C.C. Langway, Jr. (eds.), The Environmental Record in Glaciers and Ice Sheets: John Wiley & Sons Ltd., pp. 193-205. Authors at Institute of Atmospheric Sciences, Oregon Graduate Center, Beaverton, OR 97006.

Analyses of air bubbles embedded in polar ice reveal the composition of the preindustrial and ancient atmospheres. So far, extensive measurements of carbon dioxide, methane, nitrous oxide, and some chlorocarbons have been made on ice cores from both polar regions. The results provide a remarkable record of the magnitude and timing of human influences on the global cycles of these gases. Except for the chlorocarbons, for which there is no evidence of any substantial preindustrial concentrations, the other gases (CO_2, CH_4, and N_2O) started increasing only during the last 200 years as a result of the growing population and increasing needs for energy and food. The increase of N_2O probably started only a few decades ago. The record shows that CO_2 concentrations were about 280 ppmv 200 yrs ago while methane and nitrous oxide concentrations were ~700 ppbv and 285 ppbv, respectively. Now there is 25% more CO_2 in the atmosphere, 8% more N_2O, and there is more than twice as much methane in the atmosphere. At present, longer records are available for CO_2 and CH_4 which show large natural variations during glacial and interglacial periods. (Authors' abstract)

KHARAKA, Y.D., EVANS, W.C. and **RILEY, F.S.,** 1989, The application of isotopes to the origin of water and gases along the San Andreas Fault, California (abst.): Eos, v. 70, p. 1378.

KHIN, Zaw, 1988, A fluid inclusion study of Tennant Creek ironstones: Implication for exploration: Univ. Tasmania: Proterozoic gold-copper project—Workshop Manual No. 2, December 1988, p. 4-5 (abstract), p. 67-94 (paper).

A fluid inclusion study of the Au-rich zones in the Juno, TC8 and Eldorado deposits revealed Th(L-V) of 270°C to 438°C with a mode of 320°C. The nearby, overlying Cu-zone of the TC8 deposit yielded Th(L-V)L range of 231°C to 354°C with a mode of 320°C. In contrast, fluid inclusions in the unmineralised ironstone bodies (E50, E41 and E102) commonly decrepitate above 300°C and gave a Th range of 181°C to 289°C thus indicating that higher T fluids were responsible for the formation of the mineralised ironstones compared to the barren ironstones. Although Au and Cu ores were formed over a similar high T range, Cu appears to have deposited during a declining T regime.

Salinity measurements on fluid inclusions in the Au-rich zone from the Uno, TC8 and Eldorado orebodies gave a range of 14 to 45 NaCl eq. wt % with a mode of 25 NaCl eq. wt %, whereas the Cu-zone of the TC8 orebody gave 15-25 NaCl eq. wt %. Hence, although Cu and Au precipitated from hydrothermal fluids with slightly higher salinity, both mineralised and unmineralised ironstones appear to have deposited from supersaline fluids.

Preliminary Laser Raman spectroscopy analysis using the DILOR MICRODIL-28 at the BMR revealed a significant proportion of N_2 (up to 76 mole %) and CO_2 (-24 mole %) but negligible amounts of CH_4 (0.02 mole %) in the gases of the fluid inclusions in quartz from the Au-rich zones at Tennant Creek. Fourier transform infra-red spectroscopy (FTIR) and thermo-decrepitation mass spectrometry (TD-MS) methods were used to confirm the gaseous composition of the inclusion fluids.

These results have important implications regarding the deposition of gold in the ironstones, and suggest the possibility of the application of fluid inclusions to discriminate gold-bearing ironstones from barren ironstones. (Author's abstract)

The author's name is sometimes listed alphabetically (but incorrectly) as ZAW, Khin. (E.R.)

KHOSITANONT, S. and **WILLIAMS-JONES, A.E.,** 1989, The nature of Sn-W ore-forming fluids at Samoeng mine, Thailand (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-121. First author at Geol. Survey Div., Dept. Min. Resources, Bangkok 10400, Thailand.

The Samoeng mine exploits cassiterite-scheelite ores spatially associated with a calcareous roof pendant in a Triassic granite batholith. The mineralization is hosted by skarn and a small body of leucogranite. Early fluids pervasively altered marble and diopsidic calc-silicate hornfels to epidote and epidote-diopside skarn, respectively. The bulk of the mineralization is contained in later quartz and quartz-feldspar veins associated with potassic alteration envelopes (K-feldspar in the leucogranite and epidote skarn; biotite in the epidote diopside skarn). Veins in the skarns contain roughly equal proportions of scheelite and cassiterite; veins in the leucogranite contain mainly cassiterite. The deposit is cut by late tourmaline-bearing veins containing minor cassiterite.

P and S FI in quartz, cassiterite and scheelite are mainly liquid-rich aqueous and aqueous-carbonic. Rare vapor-rich inclusions are observed. Aqueous inclusions and the aqueous phase of aqueous-carbonic inclusions in quartz contain 4-10 wt % NaCl eq. and in cassiterite 0-6% NaCl eq. The carbonic phase shows a wide range of CO_2-CH_4 in quartz and a restricted range in cassiterite (XCH_4 ~ 0.2). Raman spectroscopic analyses indicate significant N_2 in some inclusions. Aqueous inclusions in quartz homogenize between 220° and 320°C and aqueous-carbonic inclusions between 240° and 360°C. The Th ranges in cassiterite are narrower, 240-360°C and 280-320°C, respectively.

It is proposed that intrusion of the leucogranite initiated a meteoric water-dominated hydrothermal system that leached Sn-W from granite and subsequently deposited these metals as a result of changes in fluid chemistry during interaction with calcareous roof pendants. (Authors's abstract)

KIDDIE, A.M. and **WOOD, S.A.**, 1989, Raman spectral studies on aqueous polynuclear molybdate solutions at elevated temperatures and pressures (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-94.

KIGAI, I.N. and **SAMOVAROV, Yu.V.**, 1989, Mineral formation from heterogeneous fluid phases as exemplified by the tin ore deposits of Trudovoye in Kirghizia: Zapiski Vses. Mineral. Obshch., v. 68, no. 2, p. 8-24 (in Russian, English abstract; translated in Int'l Geol. Rev., v. 31, no. 7, p. 714-__).

The Trudovoye W/Sn vein-type deposit with minor sulphides is located within the cupolas of postkinematic Permian granites. Early barren microcline-quartz mineralization was formed by supercritical fluids followed by liquid NaCl-KCl solutions during the rise in salinity and fluid P as indicated by fluid inclusions. From the second part of this stage to the end of the third one, mineralizing fluids consisted of chloride solution and unmixed CO_2-rich vapor phase. Lepidolite greisens and tourmalinites were formed at the beginning of the second and third stages, respectively, during interaction between diluted acid condensates of a gaseous phase and granites. Such an interaction has taken place in the time interval between opening the fractures by hydroruptures under fluid P >1.5-2.0 kbar and infilling the open space by much higher concentrated ore-precipitating alkaline solution ascending into the realm of mineralization due to the influx of meteoritic waters. These data support a genetic model for granite-related vein-type deposits associated with greisens and other acidic alterations (Kigai, 1979). This is the modernized model for vapor-dominated hydrothermal systems by White, Muffler and Truesdell (1971) for which a broad field of application is shown. It is considered that high salinity of potassic solutions is not attributed to their boiling; pre-ore explosion breccia pipes are related to "dry" CO_2 fluid separated from granitic magma prior to separation of a H_2O-rich fluid; the Nacken method of P determination is inaccurate. (Authors' abstract)

KING, R., 1989, Provinciality of $\delta^{18}O$-quartz in Archean mesothermal gold deposits of the Superior Province (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-46. Author at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, S7N 0W0.

Oxygen isotope data are reported for 39 Au deposits from the Atikokan, Pickle Lake, Red Lake, Geraldton, Wawa, Timmins, Matachewan, Noranda and Val d'Or camps of the Superior Province. The range and average $\delta^{18}O$-qtz values are (12.5-12.7; 12.6 ± 0.1 1σ, Atikokan); (13.3-13.8; 13.5 ± 0.2, Pickle Lake); (13.1-15.7; 14.6 ± 1.1, Red Lake); (12.7-13.5; 13.1 ± 0.4, Geraldton); (8.9-11.2; 10.4 ± 0.9, Wawa); (12.6-13.9; 13.2 ± 0.4, Timmins); (12.7-12.9; 12.8 ± 0.1, Matachewan); (14.3-14.7; 14.5 ± 0.3, Noranda) and (9.4-11.3; 10.6 ± 0.6, Val d'Or). The bulk of data for all Au camps clusters tightly in the 9-15% range, but small systematic variations occur between camps on a greenstone belt scale: intercamp variations may reflect (1) systematic differences in T at constant $\delta^{18}O$-H_2O; (2) differences in $\delta^{18}O$-H_2O at constant T; or (3) consistent disparities in oxygen isotope exchange during water-rock interaction between source and sink, or mixing. Calculated $\delta^{18}O$-H_2O values are 1.6‰ (300°C) to 3.2‰ (350°C) for $\delta^{18}O$-qtz = 9, to 7.6‰ (300°C) to 9.2‰ (350°C) for $\delta^{18}O$-qtz = 15. The data are not alone diagnostic of a magmatic or other fluid source, but if magmatic ($\delta^{18}O$-H_2O = 5 to 9‰), then significant fluid-rock exchange, or mixing, must have occurred, to a consistent extent within camps, but by different degrees between camps, to account for the provinciality. The provinciality in $\delta^{18}O$-qtz goes in hand with provinciality of C, Sr and Pb isotopes in Archean mesothermal deposits signifying compositionally heterogeneous source regions at a subprovince scale. (Author's abstract)

KINNUNEN, K.A., 1988, Anthropogenic decrepitation of fluid inclusions in old mines of southern Finland: Signs of fire-setting, *in* S. Autio (ed.), Current Research 1988: Geol. Surv. Finland, Special Paper 10, p. 143-145. Author at Geol. Surv. Finland, SF-02150 Espoo, Finland.

Examination of inclusions in quartz give evidence (from decrepitated inclusions with unhealed fractures) of use of fire-setting in early mining. (E.R.)

KINNUNEN, K.A., 1989, Determination of total contents of fluid inclusions in quartz using modal analysis: Examples from Proterozoic rocks and ore deposits in Finland: Bull. Geol. Soc. Finland, v. 61, pt. 2, p. 197-208. Author at Geol. Survey of Finland, SF-02150 Espoo, Finland.

A modified linear measurement procedure following Rosiwal's method to determine the total volume contents of fluid inclusions in minerals is described. The contents were determined from quartz crystals and grains in 13 Proterozoic rock and ore specimens from Finland.The quartz contained P, PS and S fluid inclusions with five main filling types identified with optical methods, a crushing stage and heating/freezing runs. In hydrothermal quartz crystals (smoky quartz), the fluid inclusion contents were high, from 1.070 to 1.661 volume %, whereas in metamorphic and magmatic quartz and in quartz veins the total contents ranges from 0.028 to 0.917 volume %. A high positive linear correlation, r = 0.915, exists between the average intercept length and total contents of inclusions in the quartz specimens studied. The mean intercept lengths of fluid inclusions in metamorphic and magmatic rock-forming quartz were exceedingly small, ranging from the limit of resolution of the optical system used up to 3.13 microns. Practical applications of the determinations of fluid inclusions contents to the purity evaluation of mineral raw materials, to the estimation of the polishing properties of the smoky quartz used as gem material and to fluid-rock interactions in connection with nuclear waste site studies in crystalline bedrock are briefly discussed. (Author's abstract)

KINO, G.S. and **CORLE, T.M.**, 1989, Confocal scanning optical microscopy: Physics Today, v. 42(9), p. 55-62. First author at Dept. Applied Physics, Stanford University, Stanford, CA.

In microscopes based on this principle a defocused image disappears instead of blurring, allowing the user to independently image different layers of transparent materials. (Authors' abstract)

KIRILENKO, I.A., **IVANOV, A.A.**, **KUDINOV, I.B.** and **ELISEEVA, V.I.**, 1989, Water-phosphate glasses: Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 154-157 (in Russian). Authors at Inst. General and Inorganic Chemistry of Acad. Sci. of USSR, Moscow.

The authors present the possibilities of glass formation in the system $Mg(H_2PO_4)_2$-H_3PO_4-H_2O on cooling from synthesis T $\leq$ 170°C to the T interval -5 to -130°C. The glass has composition $Mg(H_2PO_4)_2 \cdot nH_2O$, where n changes from 2.7 to 3.3, and it forms in the composition ranges H_3PO_4 13-68, $Mg(H_2PO_4)_2$ 0-30, H_2O 35-8 (in mol %), with a narrow range within this area, where glass formation was not possible. May be useful in interpretation of certain freezing data. (A.K.)

KISELEV, A.I. and **POPOV, A.M.**, 1989, Structure and state of the Baikal Rift on the basis of the petrologic and geophysical data: Doklady Akad. Nauk SSSR, v. 306, no. 4, p. 938-941 (in Russian).

Thermobarometric data for spinel peridotites of the upper mantle range from 850 to 1200°C with a distinct maximum at 1050-1100°C. (A.K.)

KISHIMA, Noriaki, 1989, A thermodynamic study on the pyrite-pyrrhotite-magnetite-water system at 300-500°C with relevance to the fugacity/concentration quotient of aqueous H_2S: Geochim. Cosmochim. Acta, v. 53, p. 2143-2155.

KISSIN, S.A., 1989, Genesis of silver vein deposits on the north shore of Lake Superior, Thunder Bay district, Ontario (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A130. Author at Dept. Geology, Lakehead Univ., Thunder Bay, Ontario P7B 5E1, Canada.

Ag-bearing veins occur within the curvilinear island and Mainland Belts in the Thunder Bay area and 200 km to the east in the Schreiber-Terrace Bay area. The Thunder Bay veins are hosted in Proterozoic shales and are spatially associated with Keweenawan diabase sills (Mainland Belt) and diabase and gabbro dikes (Island Belt). The veins in the Schreiber-Terrace Bay area are hosted in Archean greenstones and are not spatially related to Keweenawan hypabyssal intrusions. In spite of some mineralogical differences among the veins, geological relationships and fluid inclusion and geochemical studies indicate that all are genetically related.

Sources for the ore-depositing solutions are obscure, as magmatic sources are implausible due to the absence of contemporaneous granitic rocks and the small size of the mafic, hypabyssal intrusions. Hydrothermal-metamorphic origin of solutions due to mobilization by cooling dikes and sills is precluded by observations of pulsatory deposition with recurring thermal peaks, as evidenced in fluid inclusion studies. Fluid inclusion studies of vein material taken as much as 300 m below the ore lodes indicate that T increased with depth in the vein systems. Stable isotope and Pb isotopic studies imply a non-magmatic source of S, O, C and Pb.

The veins are believed to have formed by the mineralization of dilatant fault structures in early phases of Keweenawan rifting. Solutions derived from connate water and possibly Proterozoic seawater were heated to the range 400-450°C at depths of up to 10 km, due to anomalous heat flow associated with rifting. The solutions were of high salinity and relatively oxidized, probably at the mt-hm buffer. They were able to mobilize Ni, Co, Ag, and As, producing Ni-Co arsenide-native Ag deposits (e.g., Silver Islet), but more common native Ag with minor base metal sulfide deposits formed elsewhere due to meteoric water dilution. (Author's abstract)

KISSIN, S.A. and **SHERLOCK, R.L.,** 1989, Grant 300: The genesis of silver vein deposits in the Thunder Bay area, northwestern Ontario: Ontario Geol. Surv. Misc. Paper 143, p. 33-41. Authors at Dept. Geology, Lakehead Univ., Thunder Bay, Ontario, Canada.

Historic drill core from the Shuniah Mine and more recent drill core from the Keystone and Porcupine mines of the Thunder Bay area have provided the basis for a study of these past-producing Ag mines as a function of depth. The drill-core samples were augmented by surface samples from these mines, as well as ones from the Thunder Bay Mine. Within any given stage of deposition of quartz or calcite, fluid-inclusion Th invariably increase with depth. Precipitation was initiated from a boiling fluid at T >370°C. Cooling of the fluid and precipitation of calcite and sulphides followed generally at T declining to 100°C. Several cycles of deposition occurred, separated by fracturing events. From fluid-boiling T the depth of emplacement for the veins is 1 km with the P regime alternating between hydrostatic and lithostatic. The ore-depositing solutions appear, therefore, to have arisen from depth and to have deposited their ores in response to hydrologic factors.

Stable isotopic studies reveal that carbon in vein calcite was probably derived from organic carbon in the Gunflint and Rove Formations ($\delta^{13}C = -33‰$), which host the Ag lodes. Calcite, as well, does not occur at great depth in the vein systems. $\delta^{18}O(H_2O)$, as calculated from determinations in quartz and calcite, increases with depth, from negative to positive values, suggesting that the ore-depositing fluid was a basinal brine that became increasingly mixed with meteoric water toward the surface. Salinities are low to moderate, but invariably undersaturated, also supporting mixing. (Authors' abstract)

KITA, Itsuro, 1989, Implications of oxygen isotopes and rare gases in amorphous silica as geothermometers: Report of the Research Institute of Natural Resources, Mining College, Akita Univ., v. 54, p. 41-43 (in Japanese).

Indexed under FI. (E.R.)

KJARSGAARD, B.A. and **HAMILTON, D.L.,** 1988, Liquid immiscibility and the origin of alkali-poor carbonatites: Mineral. Mag., v. 52, p. 43-55. Authors at Dept. Geology, The University, Manchester M13 9PL, U.K.

Full paper for abstract in Fluid Inclusion Research, v. 21, p. 195. (E.R.)

KJARSGAARD, B.A. and **HAMILTON, D.L.**, 1989, Melting experiments on Shombole nephelinites: Silicate/carbonate immiscibility, phase relations and the liquid line of descent (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-50.

KLATT, E., 1988, Recognition of metamorphic pore solutions in granulites of lower crust of Sri Lanka (abst.): Fortsch. Mineral., v. 66, Beiheft 1, p. 79 (in German).

Fluid inclusions in garnet-pyroxene granulites of a profile through the SW group and Highland series of Sri Lanka were studied by means of microthermometry and laser Raman spectrometry. Granulites of the Highland series bear only rare inclusions >4 µm, i.e., adequate for measurements. They are mixed H_2O-CO_2 inclusions of moderate and high density (0.84 and 1.01 g/cm^3) and $CH_4 > N_2$ inclusions in planar distribution. Primary CO_2 inclusions were not found. Granulites of the SW group are rich in fluid inclusions. Together with almost pure CO_2 inclusions of moderate density (0.90 g/cm^3) and $CO_2 + \leq 1$ mol % CH_4, there occur also N_2 + ca. 20 mol % CH_4. Retrograde processes associated with the presence of larger amounts of fluids yielded origin of mixed H_2O-CO_2 inclusions of moderate to low density (0.86 to 0.76 g/cm^3). Aqueous inclusions of low salinity and moderate density could be measured only rarely. The N_2-CH_4-bearing inclusions with low-filling degree ($\rho < 0.4$ g/cm^3) should form during a late, retrograde stage of metamorphism. The H_2O-CO_2 inclusions have decreasing densities from NE toward SW. This P decrease may indicate either the metamorphism conditions or the reequilibration of fluid inclusions according to the P decreasing to SW. (Author's abstract translated by A.K.)

KLATT, Ekkehard, 1989a, Significance of low density N_2-CH_4 bearing fluids in high grade metamorphic rocks from Sri Lanka (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 36. Author at Dept. Mineralogy, Univ. Bonn, FRG.

Most types of FI in rocks from metamorphic terranes give evidence for syn- to early post-metamorphic entrapment or reequilibration of the pore fluid present: 3-11 kbar, 600-1100°C (Roedder, 1984). N_2-CH_4-rich inclusions seem to be the only ones which show Th L-V(V), rarely critical homogenization and hardly ever Th L-V(L) (van den Kerkhof, 1988, PhD dissert., Free Univ.). Maximal densities of 0.3 g/cm^3 calculated on the basis of microthermometric data and RL Microspectroscopy [laser Raman spectrometry?] lead towards an isostatic P of ≤2 kbar, assuming T ~800°C. This low P can only be correlated with final conditions of the retrograde path. It appears doubtful whether or not an exchange of fluid phase in the host mineral (qz, gt) is still possible at those low T. The study of N_2-CH_4-bearing inclusions in charnockites and enderbites from the SE of Sri Lanka shows the following aspects:

(1) CO_2-rich fluids (microthermometry) analyzed with the Raman probe spontaneously reacted and turned from translucent to opaque, while only N_2 and CH_4 could be detected spectroscopically: $CO_2 \rightarrow C(graphite) + O_2$ (1).

(2) According to the relationship between oxygen fugacity and the composition of the fluid phase in the system C-H-O-N-S, N_2-CH_4 inclusions are not stable at conditions where CO_2-H_2O-rich inclusions got entrapped. It can be deduced that N_2-CH_4-rich fluids do not represent a primary source.

(3) One sample had N_2-bearing inclusions surrounded by a watery phase. Probably they were descended from CO_2-H_2O-rich inclusions by a similar process as (1).

(4) Many of the samples that had CO_2 as well as N_2-CH_4 inclusions did not show lower density CO_2 inclusions in their histograms. It is assumed that lower density CO_2 inclusions have reacted to form N_2-CH_4 daughter inclusions of lowest density (1).

(5) All samples investigated never entirely had N_2-CH_4 inclusions. [No samples had only N_2-CH_4 inclusions?] They occurred together with CO_2 ones, whereas medium- to high-density CO_2 (-H_2O) inclusions quite commonly formed the only fluid phase present.

On the basis of these investigations it is assumed that most of Sri Lanka's N_2-CH_4-bearing fluid phase is present as daughter inclusions, being derived from CO_2-rich fluids which at one stage represented medium to high density condition according to the lithostatic P at (post-)metamorphic stage. (Author's abstract)

$$CO_2(+H_2O) + N_2 + CH_4 \rightarrow N_2 + CH_4(+H_2O) + C(graphite) + O_2$$

$$\rho_1(CO_2, N_2, CH_4) \rightarrow \rho_2(N_2, CH_4) \qquad \rho_2 << \rho_1(g/cm^3)$$

KLATT, E.S., 1989b, Determination of metamorphic pore fluids from high grade metamorphic rocks of the lower crust, Sri Lanka (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 57-58. Author at Dept. Mineral., Poppelsdorf Castle, Univ. Bonn, FRG.

FI in garnet-pyroxene granulites from a profile through the SW-group and the Highland-series were analyzed by means of microthermometry, laser-Raman spectroscopy, mass spectroscopy and cathode luminescence. Microthermometry showed that inclusions in quartz and garnet were of four types: (i) euhedral, almost pure CO_2 inclusions with medium to high density ($\rho CO_2 = 0.85 \rightarrow 0.92$ g/cm^3, Tm $CO_2 = -56.6 \rightarrow -57.2$°C); (ii) mixed CO_2-H_2O inclusions with medium to low density ($CO_2 = 0.78 \rightarrow 0.86$ g/cm^3); (iii) anhedral N_2-CH_4-bearing inclusions with extremely low density (Th into gas phase only at $T > -160$°C); and (iv) rare aqueous inclusions with low salinity and medium density. In a few samples clathrate melting was observed.

Laser-Raman microspectroscopy was used to analyze selected CO_2 and N_2-CH_4-bearing inclusions, from which the following observations were made: (i) CO_2 inclusions with high density contain <1 mol % methane; and (ii) N_2-CH_4 inclusions varying their composition from 50 to 80 mol % N_2 and 20 to 50 mol % CH_4. Up to 3 mol % of higher hydrocarbons (up to butane) were detected in some samples.

Between the Highland-series and the SW-group significant differences occur, with respect to chemistry, density and number of inclusions. Granulitic rocks in the ***Highlands*** have only a small number of visible inclusions. This observation corresponds very well with cathode luminescence (no palaeo-channelways) and mass spectroscopy. However, where inclusions were observed mixed CO_2-H_2O inclusions with medium to high density and N_2-rich inclusions with 35 to 40 mol % CH_4 predominate.

Granulites in the *SW-group* contain abundant FI and all four inclusion types are represented, but only a few palaeo-channelways and hydro-fractures could be found by SEM cathode luminescence. CO_2 inclusions have densities near 0.9 g/cm^3, N_2-rich inclusions hold ~20 mol %. CH_4 retrograde processes linked with a high fluid content lead toward mixed CO_2-H_2O inclusions with medium to low density. Assuming $T \approx 750$°C, the highest CO_2 densities in these mixed inclusions indicate that fluids were trapped or re-equilibrated under P ~1.5 kbar lower than in the Highlands. This regional P gradient is in very good agreement with geobarometrical results in both rock units. N_2-rich inclusions of extremely low densities (<<0.4 g/cm^3) must have been derived during a late, retrograde stage of metamorphism. (Author's abstract)

KLEMD, Reiner, 1989, P-T evolution and fluid inclusion characteristics of retrograded eclogites, Münchberg Gneiss Complex, Germany: Contrib. Mineral. Petrol., v. 102, p. 221-229. Author at Institut für Mineralogie, Universität Würzburg, Am Hubland, D-8700 Würzburg, F.R.G.

Kyanite eclogites occur as part of the Münchberger nappe pile in NE-Bavaria, West Germany. Eclogites are overprinted by subsequent amphibolite facies metamorphism. The preservation of primary eclogitic textures as well as symplectitic textures are indicative of rapid decompression. Eclogite formation is estimated to have occurred under conditions of high H_2O-activities at P between 20 and 26 kbar and T ranging between 590 and 660°C, as is shown by the coexistence of omphacite (Jd 50), kyanite, zoisite and quartz. Minimum P estimated, independent of the H_2O activity, range between 9 and 16 kbar at the relevant T. Detailed studies of FI reveal two predominant groups of aqueous-brine inclusions: high salinity (14-17 wt % NaCl eq.) and low salinity (0-8 wt % NaCl eq.inclusions. Fluid compositions of both groups of inclusions yield isochores passing close to the estimated amphibolite facies PT-field. The compositions of these fluids are in good agreement with fluid compositions considered from mineral equilibria. None of the FI has densities appropriate for eclogite facies metamorphism, but probably reflect later amphibolite facies metamorphism. (From author's abstract)

KLEMD, R., BARTON, J.M., Jr. and HALLBAUER, D.K., 1989, Fluid inclusion studies of shear zones of Witwatersrand basin (South Africa) (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 95 (in German) (supplementary issue to European J. Mineral., v. 1.).

Numerous shear zones parallel to schistosity were observed in the Ventersdorp Contact Reef. The shear zones may influence the gold distribution. Fluid inclusions were studied in quartz clefts from the shear zones. Quartz occurs with muscovite (frequently fuchsite), monazite, rutile, galena, sphalerite, pyrrhotite, chalcopyrite, and pyrite, locally with chlorite and graphite. The clefts are usually perpendicular to shear zones. Most inclusions are secondary. The H_2O-rich inclusions bear rare dms (probably graphite and carbonate); the salinity is usually between 0 and 15 wt % eq. NaCl, rarely reaching 21%. Th ranges between 95 and 230°C, Te < -30°C indicates possible presence of Ca and/or Mg in Na-K solution. The inclusions of higher salinity are associated with CH_4-rich inclusions of Th between -83 and -106°C, suggesting the presence of an admixture of N_2 or other gases. The inclusions probably originated from immiscibility of a CH_4-H_2O fluid; however, this fluid perhaps did not influence the gold distribution. (From the authors' abstract translated by A.K.)

KLEMD, R., HALLBAUER, D.K. and **BARTON, J.M., Jr.**, 1988, Hydrothermal alterations of Archean granites along the Witwatersrand (South Africa) (abst.): Fortsch. Mineral., v. 66, part 1, p. 80 (in German).

The veins of (1) K-feldspar and quartz, (2) muscovite-chlorite-quartz, (3) quartz-carbonate and (4) chlorite-hematite, all with pyrite, sphalerite, chalcopyrite, molybdenite, galena and gold formed from solutions comparable with parent solutions of the Mississippi Valley-type deposits. Diluted solutions with low CH_4 content caused propylitization and sericitization of the Archean granites and REE-Th-U mineralization. (A.K.)

KLEMD, R., HALLBAUER, D.K. and **BARTON, J.M., Jr.**, 1989, Fluid inclusion studies of hydrothermally altered Archaean granites around the Witwatersrand Basin: Mineral. and Petrol., v. 40, p. 39-56. First author at Inst. Mineral., Würzburg, FRG.

Hydrothermally altered granitic rocks occur along the northern and northwestern edge of what is classically termed the "Witwatersrand Basin." Pyrite, chalcopyrite, sphalerite, molybdenite, galena, wurtzite and other sulphides were deposited during this hydrothermal alteration, as were U and REE-rich nodules of carbonaceous matter and free Au. Heating and freezing data from S FI in igneous quartz as well as P FI in vein quartz and carbonate indicate that two main groups of aqueous FI exist. The first group has a range of Tm from 0°C to -9°C, corresponding to salinities between 0 and 13 eq. wt % NaCl. Th occurred between 130°C and 230°C. The second group of inclusions generally have Tm between -14°C and -26°C, with salinities ranging between 12 and 30 eq. wt % NaCl. Th range from 120°C to about 170°C. The low Te of -60°C to -35°C and SEM-EDX analyses of encrustations formed after evaporation of fluid in opened inclusions indicate as additional components Ca, Cl and S. Rare clathrate melting in both types of fluids indicate the presence of CO_2, CH_4 or some other clathrate compound. The low salinity fluids are interpreted to be of a meteoric, sea water or metamorphic origin, whereas the highly saline fluids are thought to be connate brines or highly evolved formation waters. (Authors' abstract)

KNIGHT, C.A. and **DeVRIES, A.L.**, 1989, Melting inhibition and superheating of ice by an antifreeze glycopeptide: Science, v. 245, p. 505-507.

The melting of pure ice single crystals can be inhibited by the presence of an antifreeze glycopeptide isolated from an Antarctic fish. This inhibition effect exhibits crystallographic dependence and can result in superheating of the crystal by heat conduction across the ice-solution interface. The antifreeze molecules inhibit melting in a manner more or less symmetrical to their well-known effect of inhibiting freezing. The melting effect is best expressed at concave ice interfaces, whereas the freezing effect is best expressed at convex ones. Both are restricted to orientations near (1010) with the particular antifreeze that was used. (Authors' abstract)

Of possible pertinence to ice melting behavior of inclusions containing organic molecules. (E.R.)

KNIGHT, C.L. and **BODNAR, R.J.**, 1989a, Synthetic fluid inclusions: IX. Critical PVTX properties of NaCl-H_2O solutions: Geochimica Cosmochim. Acta, v. 53, p. 3-8. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

Critical PVTX properties of NaCl-H_2O fluids having compositions of 0-30 wt % NaCl have been determined using the synthetic FI technique. Critical T and P increase from 374.1°C and 220 bars for pure H_2O, to 820°C and 1574 bars for 30.0 wt % NaCl. Critical specific volumes decrease from 3.11 to 1.44 cm^3/g over this same salinity range.

Critical T of NaCl-H_2O fluids over the range 0-30 wt % NaCl are described by the equation

$$T = 374.1 + 8.800\phi + 0.1771\phi^2 - 0.02113\phi^3 + 7.334 \bullet 10^{-4}\phi^4$$

where T is the critical T in degrees Celsius (±4.0°C) and ϕ is fluid composition in wt % NaCl. The critical P, determined for the intersection of the critical isochore with the critical T in P-T space, is expressed as a function of the critical T according to the relationship

$$P = 2094 - 20.56T + 0.06896T^2 - 8.903 \times 10^{-5}T^3 + 4.214 \bullet 10^{-8}T^4$$

where P is the critical P in bars (±21 bars) and T is the critical T in degrees Celsius. The critical specific volume is given as

$$SV = 3.106 - 0.5967\Psi - 0.01066\Psi^2 + 0.01267\Psi^3$$

where SV is the critical specific volume in cm^3/g ($\pm 0.02\ cm^3/g$) and Ψ is related to the salinity as

$$\Psi = \ln(\text{wt \% NaCl} + 1)\ .$$

The slopes of ($\Delta P/\Delta T$) of P-T projections of the critical isochores increase regularly with increasing salinity, from ~2.8 bars/°C for pure H_2O to ~6.8 bars/°C for a 30 wt % NaCl solution. (Authors' abstract)

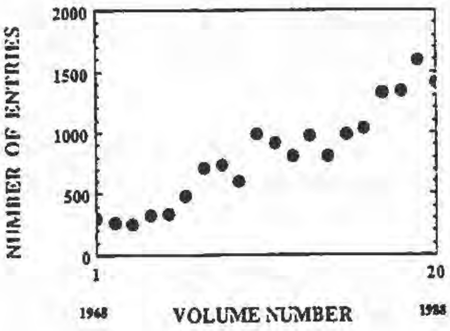
KNIGHT, C.L. and **BODNAR, R.J.**, 1989b, Raman spectroscopy of zeolites: Differenciation among natural zeolites with the Raman microprobe (abst.): Symposium GEORAMAN 89, Toulouse, France, 17-19 May, 1989, Abstracts (unpaginated); also in European J. Mineral., 1989, p. 33. Authors at Virginia Polytech. Inst. and State Univ., Blacksburg, VA.

Raman spectra of several [14] natural zeolites were collected with an Instruments SA Ramanor U-1000 Raman microprobe (RMP) [and are shown] to evaluate the potential of the RMP as a tool in the identification and characterization of these minerals. Raman activity observed in these framework silicates is largely restricted to the 600 cm^{-1} structurally sensitive region of the spectrum, implying that differences and similarities in zeolite spectra can be correlated to variations in internal structure. (From authors' abstract by E.R.)

Of pertinence to investigations of dms in FI. (E.R.)

KNIGHT, C.L., BODNAR, R.J. and **ROEDDER, Edwin**, 1989, Fluid inclusion research reference information (FIRRI): A database for fluid inclusion research (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 37. First author at Vibrational Spectroscopy Lab., Dept. Geol. Sci., Virginia Tech., Blacksburg, VA 24061.

Within the past twenty years, the number of publications related to FI research has increased markedly. In 1968, the first volume of COFFI (Commission on Ore-Forming Fluids in Inclusions) contained only 306 entries, the fourteenth volume contained 810, and the twentieth edition of FIR (Fluid Inclusion Research, nee COFFI) held 1409 entries! One negative effect of the thriving interest in FI research is the increasing difficulty researchers encounter in sorting through the literature. The general computerized library scientific search routines are often inadequate for this purpose as they rely on keywords that are entered into the database by someone unfamiliar with FI. As a solution to this problem, we intend to incorporate all of the COFFI and FIR volumes into a Fluid Inclusion Research Reference Information (FIRRI) library contained in a database program (Reflex, ™Borland/Analytica Inc.) which can be accessed with any Macintosh (™McIntosh Laboratory) personal computer. A sample FIRRI library, containing entries from the PACROFI II abstract volume, will be used to demonstrate the ease and versatility of this process and to gather input from fluid inclusionists. (Authors' abstract)



KNOEBL, Emmerich and **PEACOCK, S.M.**, 1989, Modeling metamorphic fluids produced by devolatilization of clays and calcareous sandstones under subduction zone P-T conditions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A276.

KNOX, D.A. and JACKSON, N.J., 1989, Geology of the primary china clay deposits of SW Dartmoor, Devon (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 48. Authors at School of Geol. Sci., Kingston Polytechnic, Kingston upon Thames, U.K.

The SW lobe of the Dartmoor granite constitutes the roof zone of a composite intrusion. The earliest intrusive phase has been extensively albitized. This is intruded by at least four cupolas of tourmaline syenogranite. A variety of hydrothermal phenomena are developed in the pits, beginning with quartz-tourmaline and greisen vein swarms, hydrothermal breccias, and continuing through several generations of quartz and ferruginous veins. Drilling of the deepest argillically altered zones to depths of up to 180 m below the pre-mining land surface suggests they are the stems of inverted funnel-shaped (and less common trough-shaped) kaolinized zones. Moreover, there is a close spatial relationship between the younger intrusions and the centres of kaolinization, which suggests they are primarily the effect of hydrothermal regimes focused on the syenogranite cupolas.

Fluid inclusion studies reveal at least three generations of fluid. Highly saline (17 to 37 eq. wt % NaCl), high T, Th = 230 to +400°C, fluid inclusions that characterize the early quartz tourmaline and greisen veins, and dominate the populations in granitic quartz, while the late quartz veins contain less saline fluid inclusions (0.3 to 4 eq. wt % NaCl) with minimum Tt of Th = 180 to 225°C. The coarse- and medium-grained granite lithologies have identical hypothermal signatures. This fluid probably originated from the younger medium-grained syenogranite and pervaded the older, coarse-grained lithology. Quartz in intensely kaolinized granite also displays irregular-shaped monophase and two-phase inclusions that represent the youngest hydrothermal fluid. These inclusions yield Th values of <100 to 150°C and salinities of 0 to 4 eq. wt % NaCl. (From authors' abstract by E.R.)

KOCH, B.C. and HUTCHINSON, R.W., 1989, Deposition and supergene enrichment of the Gold King-Davis epithermal precious metal lode, Silverton caldera, San Juan volcanic field, southwestern Colorado, USA (abst.): XIII Int'l Geochemical Exploration Symposium, Abstracts, Brazilian Geochemical Congress, p. 8-9. Authors at Dept. Geology and Geological Engineering, Colorado School of Mines, Golden, CO.

The epithermal Gold King-Davis precious metal vein system is a caldera-hosted, bonanza-type Au telluride vein deposit. It is peripheral to a low grade porphyry Cu-Au system of Tertiary age. The veins contain electrum (95/5 wt % Au/Ag), hessite, petzite, sylvanite, krennerite, altaite, tetrahedrite/tennantite, bismuthinite, with or without pyrite, chalcopyrite, and sphalerite. These minerals were precipitated together with quartz from hydrothermal solutions. Th of 280 to 300°C for the precipitation of the vein quartz that is the main component of the Au telluride-bearing veins. Characteristically, ore-forming solutions appear to have been predominantly of meteoric origin and were of relatively dilute nature, with fluid inclusions showing an average salinity of 1.6 wt % NaCl eq.

These auriferous solutions penetrated rocks of the caldera roof that include thick Proterozoic olivine and tholeiitic basalts, ferruginous sedimentary rocks, and minor iron formation. (From authors' abstract by E.R.)

KOCH, P.S., CHRISTIE, J.M., ORD, Alison and GEORGE, R.P., Jr., 1989, Effect of water on the rheology of experimentally deformed quartzite: J. Geophys. Res., v. 94, no. B10, p. 13,975-13,996.

KOEBERL, C., FREDRIKSSON, K., GÖTZINGER, M. and REIMOLD, W.U., 1989, Anomalous quartz from the Roter Kamm impact crater, Namibia: Evidence of post-impact hydrothermal activity?: Geochim. Cosmochim. Acta, v. 53, p. 2113-2118. First author at Lunar and Planetary Institute, 3303 NASA Road One, Houston, TX 77058.

Centimeter-sized quartz pebbles have been found on the rim of the Roter Kamm impact crater. The Roter Kamm crater has a diameter of ~2.5 km and is situated in the Namib Desert, SWA/Namibia. Because of the sand coverage, impact products (breccias, impact melt, shocked rocks) are exposed exclusively in the form of ejecta on the crater rim. The quartz pebbles were found close to the main deposits of the impact breccias and show signs of wind abrasion. Thin sections revealed that the pebbles consist of individual quartz domains that are up to 1 mm in size. Under crossed nicols (polarized light), all individual domains show extinction almost simultaneously within ±2, which is a rare phenomenon. Microprobe studies, neutron activation analyses, and X-ray diffractometry confirmed that the material consists of pure quartz. The quartz contains three different types of fluid inclusions: P inclusions (size ~5-10 μm) that record the formation conditions of the quartz, very small (<1 μm) S inclusions associated with the grain boundaries, and late inclusions of irregular size. Freezing point depression measurements of the P inclusions indicate fluid salinities between 18.3 and 19.6 wt % NaCl. Th for the P inclusions range from 165 to 250°C. The quartz and the P inclusions may provide evidence for a post-impact phase of extensive hydrothermal activity, generated by the residual heat from the kinetic energy of the impact. (Authors' abstract)

KOERNER, R.M., 1989, Ice core evidence for extensive melting of the Greenland ice sheet in the last interglacial: Science, v. 244, p. 964-968.

Based in part on the gas content of the ice (from gas inclusions). (E.R.)

KOHLSTEDT, D.L., 1989, Chemical analysis of grain boundaries in an olivine-basalt aggregate using high-resolution analytical electron microscopy (abst.): Eos, v. 70, p. 502. Author at Dept. Materials Sci. and Engrg., Cornell Univ., Ithaca, NY 14853.

Even a small amount of melt can cause a substantial reduction in the high-T creep strength of a rock, if the melt wets the grain boundaries. Therefore, chemical analyses have been performed on an olivine-basalt aggregate with a high-resolution analytical electron microscope to test for the possible existence of a glass phase (i.e., quenched melt) in the grain boundaries. Ten high-angle and five low-angle grain boundaries were probed in a sample containing 1.6 wt % basalt which had been hydrostatically hot-pressed at 1 GPa, 1245°C for 168 hr. To determine the presence or absence of basalt, the X-ray spectra were examined in particular for Ca and Al because these two elements partition primarily into the basalt. The Ca Kα and Al Kα peaks were absent (i.e., below background) in the spectra from all fifteen boundaries which were probed. To obtain a quantitative estimate of the maximum amount of basalt which could be present in these boundaries, the measured X-ray spectra were compared with composite spectra generated from weighted sums of a spectrum collected from a pocket of basalt with one collected from an olivine grain. The weighting factors took into account the size of the incident electron beam, 3 nm, and the beam spreading which occurs as the electrons travel through the sample. This analytical technique demonstrates that the upper limit for the amount of basalt which could be present as a discrete layer in a grain boundary is between 0.2 and 0.5 nm. This observation indicates that basalt did not wet the grain boundaries at high T. Consequently, the basalt is unlikely to cause more than a factor of three decrease in the creep strength of these partially melted rocks, relative to the strength of a melt-free aggregate. (Author's abstract)

KOIVULA, J.I. and **KAMMERLING, R.C.**, 1989, Examination of a gem spinel crystal from the Pamir Mountains: Z. Dt. Gemmol. Ges., v. 38, no. 2/3, p. 85-88.

This article reports on the gemological properties shown by a gem-quality pink spinel crystal from the Pamir Range in the Soviet Union. The suite of [mineral] inclusions observed in this crystal is discussed, and the morphology of the crystal itself is described. (Authors' abstract)

KOJIMA, Shoji, SUGAKI, Asahiko, SHIMADA, Nobutaka and **KITAKAZE, Arashi**, 1987, Study of genetic condition based on fluid inclusion and sphalerite composition of the Bolivian-type polymetallic ore deposits (abst.): Abstracts, Joint Mtg. Min. Soc. Jap./Soc. Min. Geol. Jap./Jap. Assoc. Min., Pet., Econ. Geol. (in Japanese, translated by Y. Seki). First author at Fac. of Sci., Tohoku Univ.

Genetic conditions at four types of polymetallic hydrothermal ore deposits distributed in the eastern Andes of Bolivia were studied. Sn-W-Bi type (Viloco, Tasna, Chorolque, etc.) has Th of 250-530°C and salinity (NaCl eq.) of 25-55 wt %. Estimated sulfur gas fugacity (log fS_2) based on Th and FeS amount in ZnS is -4.5 to -10.5. Sn type (Huanuni, Morococala, Avicaya, Siglo XX, etc.) has Th of 240-420°C, salinity of 8-38 wt % and log fS_2 of -6.5 to -13.0. Sn-Ag type (Bolivar, Potosi, Tatasi, etc.) has Th of 180-360°C, salinity of 2-20 wt % and log fS_2 of -8.0 to -14.5. Ag-Pb-Zn type has Th of 150-350°C, salinity of 1-13°C and log fS_2 of -8.0 to -15.5. Estimates of fO_2 for the types with Sn indicate values intermediate between NMO and QMF buffers, so fO_2 is considered to have been buffered by the surrounding host rocks. (Authors' abstract)

KOLPAKOVA'N, N., KOSERENKO, S.V., BARANOVA, N.N., RYZHENKO, B.N., DAR'INA, T.G., SAVEL'EVA, N.I., KOLOTOV, V.P. and **GORIACHEV, N.A.**, 1988, Gold, antimony and sulfide sulfur in hydrothermal solutions and formation of gold deposits, *in* Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-forming Fluids and Ore Genesis, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Nankova Dumka Press (ISBN 5-12-001072-5), p. 122-130 (in Russian). Authors at Inst. Geochem and Anal. Chem., Moscow, U.S.S.R.

The data were obtained on Au, Sb and sulfide sulfur concentration of the three types of Au deposits: Au-sulfide-telluride (I); Au-sulfide (II); and Au-Bi (III). Decrepitation technique and 6 N HCl solutions for prevention of sorbtion of Au on quartz surface and Sb hydrolysis were used as leachate solutions for metal determinations. Neutron activation analysis was used. Sulfide Ag electrode was used for determination of sulfide sulfur concentration (ΣH_2S + HS^-). The determinations were made after grinding samples in 0.01 M NaOH solution in Ar atmosphere.

Concentration of sulfide sulfur in fluid inclusions in deposit I varied in the range from 10-5 M to 0.1 M, deposit II from 10^{-4} to 10^{-2} M, and deposit III 10^{-3} M (mean value). For type I and II deposits, a wide range of Au concentration was established (10^{-6} - $5 \cdot 10^{-5}$ M) in the fluid inclusions There is a correlation between concentration of Au and sulfide sulfur for these deposits. Deposit III showed a very small variation in Au concentration (10^{-6} - $5 \cdot 10^{-6}$ M [sic].

Sb concentration for deposit I was $5 \cdot 10^{-3}$ M (mean value), upper limit was 0.6 M (for fluid inclusions in quartz from quartz-antimonite ore bodies), for deposit II—$(1\text{-}3) \cdot 10^{--3}$ M, for deposit III—from 10^{-4} M to 10^{-5} M.

On the basis of these data, a thermodynamic calculation of the Au-Sb-sulfide complexing in the system Au-Sb-S-Cl-Na-H_2O [was made]. It was shown that hydrosulfide and mixed sulfide-Au-Sb complex compounds of Au ($AuHS^o$, $Au(HS)_2^-$, $H_2AuSbS_2^o$, $HAuSbS_2^o$ predominate in the neutral sulfide-bearing solutions ($\Sigma H_2S + HS \leq 10^{-3}$ M). In acid chlorine-bearing solutions Au is transported as $AuCl_2^-$. (Authors' abstract, translated by T. Sushchevskaya)

KONECNA, Monika, 1989, Fluid inclusion and silicate thermobarometry on lherzolite xenoliths and olivine megacrysts from alkali basalts of southern Slovakia (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 9. Author at Dept. Mineral. & Petrol., Comenius Univ., 842 15 Bratislava, CSSR.

Mineralogical and FI studies were performed on xenoliths and megacrysts from nephelinic basanites near Filakovske Kovace (southern Slovakia). As first stated by Hovorka - Fejdi (1980), composition of xenolith minerals (Cr-diopside, Al-spinel, Mg-rich olivine) is similar to this of type world localities and is suggestive for their upper mantle origin.

Xenolith olivine and diopside as well as olivine megacrysts contain numerous melt and gas inclusions, isolated or arranged along healed fractures, ranging in size from 5 to 25 µm. Gas phase of melt inclusions occupy 5-10 vol. %. Rarely observed trails with various melt-to-gas ratios indicate immiscibility of both phases at the time of entrapment.

Melt inclusions have Th ≥ 1150°C. At this T strong oxidation and darkening of olivine grains made observations of inclusions impossible. Th of gas inclusions were scattered within the range from -13 to +16.5°C corresponding to the density 0.8-1.01 g/cc, if pure CO_2 is considered. However, Tm from -62.1 to -70.9°C are much lower than Tm of pure CO_2 (-56.6°C) thus indicating the presence of additional gas species. Raman analyses performed by J. Dubessy and J. Durisova in CREGU (Vandoeuvre-les-Nancy, France), recorded also the presence of CO (1.21-2.38 mol %) and N_2 (0.14-0.38 mol %). This is probably the first direct determination of N within inclusions from upper mantle minerals.

Equilibration conditions of xenolith minerals were calculated using various thermobarometers based on chemical composition of coeval phases. Calculated T and P vary between 965-1041°C and 8.5-18 kbar.

T of diopside and olivine crystallization is assumed to be about 1200°C and corresponding fluid P, calculated from the MRK state equation and a, b parameters from Holloway (1981), may have reached 8-11.3 kbar. These values are lower than equilibration P probably due to density reduction caused by decrepitation of inclusions and partial loss of volatiles during ascent of basaltic magma to the surface. FI and silicate barometry are in good agreement with geophysical data for the area studied, where MOHO discontinuity was detected at the depth of 28 km (Blizkovsky et al. 1986), if compared with the depth of 33-60 km during silicate equilibration and 29-40 km derived from inclusion data. (Author's abstract, references deleted)

KONTAK, D.J. and **SMITH, P.K.,** 1989a, Fluid inclusion studies of quartz vein polytypes from the Beaver Dam and Caribou Gold Deposits, Meguma Zone, Nova Scotia: Evidence for a single vein-forming event (abst.): Atlantic Geology, v. 25, p. 162. Authors at Nova Scotia Dept. Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1, Canada.

There have been numerous theories advanced for the genesis of the auriferous quartz veins hosted by the Lower Paleozoic Meguma Group of southern Nova Scotia. In almost all models the veins have been considered to represent multiple episodes of vein injection that collectively lasted for considerable time because of the highly variable states of strain presently observed (e.g., early folded bedding parallel vein versus late ac vein). We have interpreted the veins as representing a single hydrothermal event, the consequence of fluid penetration into a subvertical shear regime at ca. 370 Ma; the differential states of strain within individual quartz veins merely reflect relative timing of vein formation (i.e., highly strained early versus low strain late). One way to test this "single-vein forming event" model is to examine the nature of the vein-forming fluid as preserved in fluid inclusions—a single population of fluid inclusions would at least corroborate the model suggested.

Petrographic examination and thermometric measurement (~2000 to date) of fluid inclusions from quartz and carbonate material from all vein types (bp, ac, en echelon, bull-crosscutting) in the Beaver Dam and Caribou deposits reveals very uniform features for all samples. The dominant fluid inclusion type consists of a mixed H_2O-CO_2-CH_4 brine with a uniform composition of XCO_2 - 0.10±0.5, XCH_4 - <0.05 and wt % eq. NaCl - <10. The minor but persistent presence of vapor-rich CO_2 inclusions and low salinity (i.e., <10 wt % eq. NaCl) aqueous-type inclusions is interpreted to indicate that incipient unmixing occurred during vein formation of both deposits. The only difference noted in thermometric data for the two areas is in final T_h, which is 300±20°C for Beaver Dam and 275±10°C for Caribou.

Analyses of leachates (N - 18) from ultrapure quartz separates from all vein types at the Beaver Dam deposit give exceptionally uniform results (cationic concentrations: Na-0.511±0.49, Ca-0.255±0.108, K-0.021±0.004, Mg-0.0058±0.0034, Fe-0.0009±0.0002). These data are consistent with the fluid inclusion observations noted above which indicate the presence of a single fluid inclusion population and, hence, a common fluid chemistry.

The fluid inclusion data for the two deposits are interpreted to indicate that all vein types formed from a single, homogeneous fluid which was focused into structurally favorable sites during one hydrothermal event. The variability of inclusions reflects incipient unmixing of this H_2O-CO_2-CH_4 fluid as a result of P and T changes. The data do not support models invoking multiple generations of veins related to different fluids. An important extension of this study is that auriferous versus barren veins apparently have the same fluid inclusion population. (Authors' abstract)

KONTAK, D.J. and **SMITH, P.K.,** 1989b, Rare-earth-element variability in gangue mineralogy of Meguma-hosted auriferous quartz veins, Nova Scotia: Possible consequence of unmixing of H_2O-CO_2-NaCl-CH_4 fluids (abst.): Atlantic Geology, v. 25, p. 162-163. Authors at Nova Scotia Dept. Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1, Canada.

Auriferous quartz veins in the metaturbiditic Lower Paleozoic Meguma Group of southern Nova Scotia contain a diverse assemblage of gangue minerals. For example, in addition to quartz, native gold and sulphides there occurs plag, Kf, tour, carb, chl, bt, ms, gar, apatite, amph, epdt, sch and andalusite, albeit in highly variable quantities. Paragenetically an early stage of Ca-rich plag ($An_{30.70}$)-tour ($sch_{50}.drv_{50}$)-bt (Mg-0.50±0.05).gar ± sulphides is overprinted by a later hypogene assemblage of alb-ms-chl-sph-carb-sch ± sulphides (±Au). Stage 1 is constrained by garnet-biotite geothermometry at ca. 475°C, while the latter stage is considered to have formed at 300±50°C (O isotopes, fluid inclusions). Fluid inclusion studies indicate the vein-forming fluid was a mixed H_2O-CO_2-CH_4 (XCO_2-0.10±0.05) brine with 4.6 wt % eq. NaCl (+Ca, K, Fe, Mg). Evidence of fluid unmixing is present in most specimens examined.

We have analyzed plag, chl, bt, apatite and carb from quartz veins in a variety of Au deposits for trace elements, including the REE's. Although major element chemistry of the minerals is remarkably uniform within a deposit, the trace- and RE-element chemistry (using chondrite-normalized REE profiles, or CNRP) is highly variable. However, we do note that coexisting vein phases (e.g., bt-plag) give comparable CNRP's, indicating that local equilibrium conditions prevailed between mineral phases and that the fluid was of uniform composition with respect to the REE's. The CNRP's for the vein minerals contrast markedly with the shale-like CNRP for the Maguma Group host rocks.

Possible explanations for the observed variability of the CNRP's of the gangue minerals in the Au veins include: (1) variable mixing of two (or more) fluids with contrasting absolute REE contents; (2) variable contamination of wall rock by a single, homogeneous (with respect to REE's) fluid; and (3) unmixing of the ore-forming fluid due to H_2O-CO_2 immiscibility. The third possibility is considered the most viable considering the known temperature constraints for the mineral paragenesis, uniform isotopic (O, C, S) compositions of vein minerals, fluid inclusion thermometric measurements and leachate analyses, and constant CNRP's for fresh and altered wall rock. In addition, the experimental and empirical observation that LREE's and HREE's are preferentially partitioned by Cl and CO_2 complexes, respectively, would be consistent with the observations noted above. (From authors' abstract by E.R.)

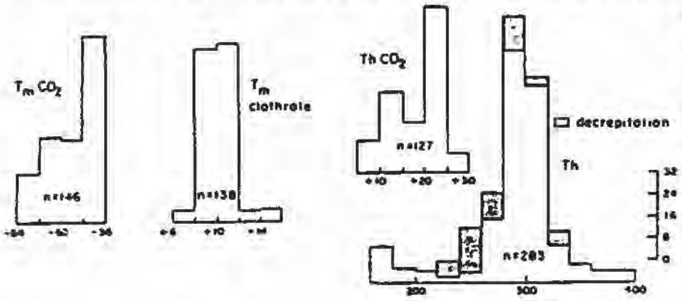
KONTAK, D.J. and **SMITH, P.K.**, 1989c, Fluid inclusion study of quartz vein polytypes in the Beaver Dam gold deposit, Meguma terrane, Nova Scotia, Canada (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 38. Authors at Nova Scotia Dept. Mines and Energy, P.O. Box 1087 Halifax, Nova Scotia B3H 2X1.

The Beaver Dam Au deposit (ca. 2 x 10^6 tons/0.27 oz. per ton), hosted by Cambro-Ordovician metaturbiditic sediments of the Meguma Group, consists of several vein types, including bedding parallel, discordant, ac and fissure types. The vein package is located on the southern, overturned (075°N) limb of a NE-trending anticline. Vein emplacement occurred post regional folding during localized, sub-vertical shearing along this attenuated limb. Vein morphology and deformation histories suggest a progressive shearing event with transient brittle-ductile conditions. Vein mineralogy is dominated by quartz with lesser amounts of tour ± carb ± chl ± plag ± bi ± ms ± gt ± apatite ± scheelite ± sulphides ± tellurides and native Au (fineness >900). $^{40}Ar/^{39}Ar$ plateau (>90% gas) ages of 370 Ma for vein micas confirm field relationships indicating quartz veining and attendant wall rock alteration coincided with intrusion of the nearby (ca. 2 km) 370 Ma, peraluminous River Lake pluton.

All vein types have been examined for FI and a remarkable uniformity is noted. Thus, regardless of vein type, mineralogy, presence/absence of Au mineralization and deformation, the same FI population is observed. In least deformed samples inclusions are typically 5-50 μm size and occur as isolated clusters or confined to planar arrays; unequivocal evidence of P origin is lacking, hence, all inclusions are grouped as S.

Three types of inclusions are observed (see Fig. 1 for thermometric data), viz. (1) low-salinity (<10 eq wt % NaCl) H_2O-CO_2 inclusions with variable CO_2 contents (avg 20 mole %) and CH_4; (2) CO_2-rich inclusions containing minor H_2O and variable CH_4 (0-30 mole %); and (3) low-salinity ($x = 6.4 \pm 3.1$ eq wt % NaCl, n = 43) H_2O inclusions. Coexistence of all three types is common, but type 1 inclusions dominate (>90%). Although Th data indicate variable contents of CH_4 and density of type 1 inclusions ($\rho = 0.5$-0.97 g/cc for CO_2 phase), for isolated populations the data are very uniform. Final Th for all inclusion types show a broad range with a marked peak at ca. 300°C, which also forms the mean for Td.

Leachate analyses (n = 18) of all vein types show that the aqueous fluids were uniform in solute composition (e.g., atomic ratios Na/K = 26.3 ± 7.9, Na/Ca = 3.0 ± 1.8). Cationic proportions of analyzed elements normalized to Na = 1 are as follows: Ca = 0.44, K = 0.041, Mg = 0.011, Fe = 0.0018. Collectively the FI data are interpreted to indicate that a single, low salinity CO_2-H_2O fluid dominated the mineralizing event at Beaver Dam. A mechanism involving seismic pumping on the ambient P such that a range of fluid compositions were periodically evolved. The lack of correlation between Au mineralization and degree of effervescence suggests an alternative mechanism controlled Au precipitation. (Authors' abstract)



KORMUSHIN, V.A. (ed.), 1988, Practical thermobarogeochemistry—Abstracts of the interdisciplinary seminar, June 2-4, 1987, Alma-Ata, "Nauka" Pub. House, Alma-Ata., 2 vols., 500 copies printed (in Russian, translation of contents by I. Kulikov).

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KORMUSHIN, V.A., 1989, How to determine concentration of ore- and rock-forming elements in ore-forming solutions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 41. Author at Inst. Geol. Sci., Kazakh SSR Acad. Sci., Alma-Ata, Kalinin St. 69-A 480100, USSR.

Earlier (1), on the basis of diversified analysis of gas and liquid phases of inclusions, techniques for reconstructing composition and mineral-forming solution concentrations were developed, according to which the concentration of each component, water included, was expressed in the common metering system - in kg of a substance in a volume of m^3 (kg/m^3). This technique (1,2) ignores the content of rock-forming components such as SiO_2, Al_2O_3, and others, and ore elements as well.

If the content of ore elements is, to a certain extent, possible to assess, then that of ore-forming components constituting this host mineral is not possible to assess. In order to avoid this paradox it is suggested that the concentration of these elements be derived by their solubility in an autoclave in a reconstructed solution at a T of FI homogenization.

References: 1. Kormushin, V.A., Ivkina, I.N., Darbadaev, A.B., et al. Reconstruction of mineral-forming solutions in accordance with microinclusions in minerals. Abstracts of 27th International Geol. Congress, 1984, 5, 84. 2. Kormushin, V.A. Techniques of studying gas-liquid inclusions in minerals. Alma-Ata, "Nauka," 1981, 153 pp. (Author's abstract)

KORMUSHIN, V.A., LIPOVA, Z.M. and ISAYEVA, L.D., 1989, Preparation peculiarities of differentiated aqueous and gaseous extracts from minerals (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 39. Authors at Inst. Geol. Sci., Kazakh SSR Acad. Sci., Alma-Ata, Kalinin St. 69-A 480100, USSR.

Analysis of aqueous extracts from minerals possesses a number of advantages as compared to other methods of chemical analysis of FI compositions. Firstly, the completeness of extracted components, and, secondly, by increasing the mineral quantity it is possible to obtain the required concentration of the component under analysis so as to insure analytical reliability.

In minerals there are, as a rule, several genetical groups of FI, and it is imperative that these groups be extracted separately, i.e., it is necessary to prepare several aqueous extracts from one sample, each of which should correspond to a specific genetic group of FI (P, S). The gaseous component of FI is a constituent part of the mineral-forming solution and it should be taken into account in the mineral-forming solution composition. This task is accomplished by extracting both gas and substances dissolved in the inclusions from the same sample, using the following steps:

A. Preparation work: 1. FI, in particular, the Th of inclusions from each genetic group are studied by the method of mineralothermometrical analysis (Ermakov and Dolgov, 1979; Roedder, 1984). 2. The T of mineral gaseous extraction (Td) is determined by the method of thermovacuumetry on an instrument (Kormushin, 1962, inventor's certificate of the USSR No. 144309; Dolgov, 1965, Mineralogical Thermometry and Barometry, p. 142-146), then by correlating the data on Th and Td, T-genetic groups are distinguished according to which gaseous and aqueous extracts are to be prepared.

B. Preparation of gaseous extract: 1. A sample is placed in a special reactor connected to the gas chromatograph. By blowing the carrier gas (helium or argon) through the reactor, adsorbed gases are removed from the sample, while the sample is being heated to 10-20°C lower than that at the start of gas extraction of the first T-genetic inclusion group. The quality of sample purification from adsorbed gases is monitored with the chromatograph. 2. After purification is complete, T is increased up to Td of the first T-genetic group of FI.

C. Preparation of aqueous extract: When gas is removed as a result of sample heating, FI explode and their contents, partially or fully, are found on the surface of the mineral grains. An aqueous extract is then made in the same reactor (without moving the sample) by washing the sample with a small amount of double-distilled water. This ensures extraction of ≥90% of salts. The aqueous extract is ready for analysis without evaporation.

After the aqueous extract has been prepared the reactor is connected to the gas line of the chromatograph and gas removal from the next T-genetic inclusion group is carried out as outlined in point B.

The aqueous extract analysis is made by standard methods: atomic absorption, colorimetry, etc. (Kormushin, 1981, Analysis methods for gas-aqueous inclusions in minerals, Alma-Ata, "Nauka" Press, 153 pp.). (Authors' abstract)

KOROTAYEV, M.Yu., 1987, Phase equilibria in the SiO_2-NaCl-H_2O-CO_2 system and problems of hydrothermal ore generation: Doklady Akad. Nauk SSSR, 1987, v. 296, no. 3, p. 715-718 (in Russian; translated in Doklady Acad. Sci., v. 296, no. 1-6, p. 193-196, 1989). Author at Univ. Moscow.

The SiO_2-NaCl-H_2O-CO_2 system is the closest analog of natural hydrothermal solutions. Phase equilibria in this system have been analyzed by using the results of experimental studies of its boundary binary and ternary subsystems [1, 4, 7, 11-15], and by applying the principles of topological transformations and the systematics of phase diagrams involving components [1]. The main distinctive characteristic of this system is heterophase hydrolysis, the reaction for which, in the presence of quartz, is $2NaCl + 2SiO_2 + H_2O = Na_2S_2O_5 + 2HCl$. The gas phase becomes enriched in HCl and the liquid phase in $Na_2Si_2O_5$ [5]. The compositions of the phases in this system will lie within a four-sided pyramid (Fig. 1a). (From author's text)

KORZHINSKII, M.A., 1989, Behavior of dissolved salts in chloride-carbon dioxide-water fluid: Acid-salt effects and characteristics of their occurrence: Geokhimiya, 1989(12), p. 1763-1770 (in Russian, English abstract). Author at Inst. Eksp. Miner., Chernogolovka, U.S.S.R.

In experiments at T = 400-500 and 700°C and P = 1-2 kbar, a behavior of acid component HCl and chlorides NaCl, $MgCl_2$, $CaCl_2$, $FeCl_2$ in hydrothermal fluid has been studied at the presence of CO_2 and NaCl and predetermined activities of HCl^0 (buffer Ag + AgCl - Fe_2O_3 + Fe_3O_4) and MO_x (nonvariant mineral association). It has been found that in high-T area a behavior of HCl and chloride salts in fluid systems with CO_2 and NaCl is principally different. Factors promoting acidic and alkaline effect of fluid on the equilibrium association have been analyzed. (From author's abstract)

KOSTER van GROOS, A.F., 1989, The upper three-phase region in the join Na_2CO_3-H_2O (abst.): Eos, v. 70, p. 483. Author at Dept. Geol. Sci., Univ. Illinois Chicago, Chicago, IL 60680.

A DTA study of the join Na_2CO_3-H_2O was carried out to 4 kb P. The phase relations in this join are ternary rather than binary, with the vapor phase enriched in CO_2 with respect to a coexisting liquid. The first critical end point is near the critical point of H_2O. The second critical endpoint was located at 505 ± 5°C and 1510 ± 10 bars with a composition containing 80 ± 3 wt % H_2O. These conditions indicate that Na_2CO_3-rich fluids in the crust and mantle are supercritical fluids rather than liquids. The recognition that hydrous alkali-rich carbonate fluids in the mantle are supercritical has important bearing on the origin of carbonatites and kimberlites, and on mantle metasomatism in general. (Author's abstract)

KOTEL'NIKOVA, Z.A. and **KOTEL'NIKOV, A.R.**, 1988, Experimental study of fluid inclusions in minerals: Geokhimiya, no. 8, p. 1075-1083, 1988 (in Russian, translated in Geochem. Int'l, v. 26, no. 3, p. 1-8, 1989). First author at Lithosphere Inst., USSR Academy of Sciences, Moscow, U.S.S.R.

Abstract in Fluid Inclusion Research, v. 21, p. 205, 1988. (E.R.)

KOTELNIKOVA, Z.A., **KOTELNIKOV, A.R.** and **GANEEV, I.G.**, 1989, Synthetic fluid inclusions: The system H_2O-CO_2-NaCl (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-217. Authors at Inst. Lithosphere and Inst. Experimental Mineralogy, Academy of Sciences of the U.S.S.R. [Paper not presented at Congress. E.R.]

Shelton and Orville (1), Sterner and Bodnar (2), Bodnar et al. (3) were the first to show the possibility of synthesis of fluid inclusions and prospective for using them as an original sampling to study phase equilibria in the systems H_2O-NaCl and H_2O-KCl. In that study, we have considered the adequacy of trapping of synthetic fluid inclusions to [reflect] the run conditions by using the H_2O-NaCl and H_2O-CO_2 systems and determined the position of an immiscibility region in the H_2O-CO_2-NaCl system at T = 600, 800°C and P = 2 kbar.

Experiments were made in a high P hydrothermal cold seal installation with external heating. It took 1-1.5 hour to reach run conditions and ~10 minutes to quench. The experimental technique was similar to that described by Bodnar et al. (3). After the run, the amounts of H_2O and CO_2 in the capsule were controlled by weighing, with freezing in LN_2 before opening.

Data for the systems H_2O-CO_2 (800°C) and H_2O-NaCl (800°C, 2 kbar) are in the tables.

P, kbar	H_2O:CO_2 initial	Density CO_2, g/sm^{3}*	V_v:V_L	H_2O:CO_2 calculated
1.65	0.1:0.9	0.15	0.7:0.3	0.14:0.86
1.65	0.4:0.6	0.24	0.85:0.15	0.37:0.63
1.45	0.2:0.8	0.20	0.8:0.2	0.25:0.75
3.65	0.5:0.5	0.83	0.75:0.25	0.51:0.49

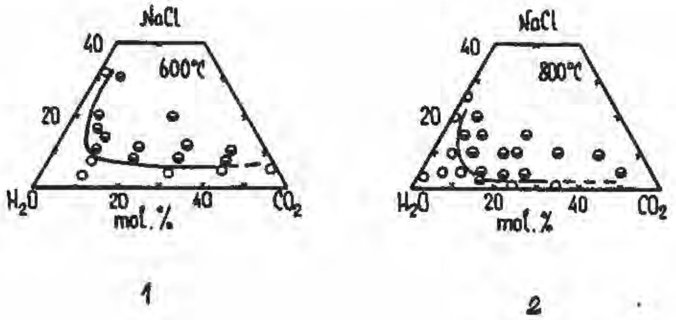
*sic

NaCl (initial) % by mass	Melt, °C	NaCl in inclusions
5.7	-3.2 – -3.6	5.2-5.9
11.3	-6.8 – -7.5	10.4-11.1
17.0	-13.1 – -18.8	17.0-18.8
22.7	-21.5 (eutectic)	23.3

The inclusions [from trapping a] homogeneous fluid belong to one and the same type. They are characterized by the constant volume ratios and phase transition T. If there were immiscible fluids, several types of inclusions with different T of phase transition were formed. The state of fluid in the experimental conditions can be determined using these characteristics. However, to interpret the data one should take into account the effect of a high T hydrolysis which has not been studied in considerable detail so far. At 600°C, pH of the gaseous and liquid phases in the H_2O-NaCl system correspond to 4 and 6, respectively, but with increasing T, the ΔpH increases too (4). The hydrolysis can cause the interaction between NaOH and quartz resulting in an easily soluble sodium disilicate which complicates considerably the phase relations in the fluid.

The inclusions with the H_2O-CO_2-NaCl were synthesized at T = 600, 800°C and P = 2 kbar. The position of the phase boundary of the system was determined by studying of the inclusions (Figs. 1,2). The figures demonstrate the region of immiscibility covering quite a wide field which widens with increase of T. The composition of the immiscible fluids have not been determined. Thus, the obtained data indicate that the immiscibility phenomena of fluids is of greatest geochemical importance at the stage of postmagmatic and metamorphic processes.

References: (1) Shelton, K.L. and Orville, P., 1980, Am. Mineral., 65, 1233-1236. (2) Bodnar, R.J. et al., 1985, Geochim. Cosmochim. Acta, 49, 1861-1873. (3) Sterner, S.M. and Bodnar, R.J., 1984, Geochim. Cosmochim. Acta, 48, 2659-2688. (4) Alekhin, Ju.V. and Vakylenko, A.G., 1987, Russian Geochem., no. 10, 1468-1481. (Authors' abstract)



Figures 1 and 2. Diagrams of the system H_2O-CO_2-NaCl at P = 2 kbar, T = 600 (Fig. 1) and 800°C (Fig. 2). Open circles—homogeneous fluid, half-open—heterogeneous fluid.

KOVALENKER, V.A., NAUMOV, V.B. and PROKOF'YEV, V.Yu., 1988, Heterogenization of fluids as one factor in precipitation of the commercial associations during formation of gold ore and gold-silver deposits: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 21 (in Russian). First author at Inst. of Geol. of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, U.S.S.R.

Au and Au-Ag deposits of the paleovolcanic areas of Middle Tyan-Shan', Little Caucasus and W. Carpathians have commercial stages (Au and Au-Ag) formed from boiling mineral-forming solutions. (A.K.)

KOVALENKO, V.I., HERVIG, R.L., NAUMOV, V.B., SOLOVOVA, I.P, and SHERIDAN, M.F., 1989, Using ion probe for analysis of rare elements and water in pantellerites of Pantelleria Island, Italy: Geokhimiya 1989, no. 9, p. 1307-1319 (in Russian, English abstract).

Using ion probe the contents of H_2O and Li, Be, B, F, P, Rb, Sr, Ba, Y, Zr, Nb, Sn, Cs, REE have been determined in the first time in the melt inclusions of natural magmas of pantellerites. Partition ratio (K) of these elements between the melt and phenocrysts of anorthoclase, hedenbergite, enigmatite, quartz, apatite have been evaluated. Except Sr, Ba and REE for apatite all other partition ratios determined are significantly less than 1. Variations of K are controlled by crystalline structure of the minerals. Maximum values of K have been determined for elements which are crystallochemically close to the elements of host minerals. The pantellerite magma before the eruption contained $\geq$4 wt % of H_2O, the loss of which during the eruption was accompanied by significant loss only of Na and Cl along with preservation in magma of the predominant amount of the studied rare elements. Crystallization of the magma before the eruption began at 850°C (anorthoclase) continued down to 760°C (quartz) and lower and was accompanied by intensive accumulation in the residual melt of the most part of the lithophile rare and volatile elements. (Authors' abstract)

KOVALENKO, V.I., HERVIG, R.L. and SCHAUER, S., 1989, Volatile contents of pantellerite (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 156. First author at Inst. Geology of Ore Deposits, USSR Academy of Science, Staromonetny 35, Moscow, U.S.S.R.

In an ongoing project to understand the origin of peralkaline rocks, we have been studying the volatile and trace element chemistry of trapped melt inclusions in phenocrysts from pantellerite and related rocks from Pantelleria. For this work we used the ion microprobe because of its high spatial resolution and good sensitivity for many elements from H to U. A preliminary study of a very trace element-enriched pantellerite showed that trapped melt inclusions in quartz and anorthoclase phenocrysts were also rich in H_2O, F and Cl (4 wt % H_2O, 0.5 wt % F, 1 wt % Cl). Analyses of the pantellerite matrix glass showed similar F, slightly lower Cl, but much lower H_2O ($\leq$0.5 wt %). They concluded that when this pantellerite erupted, H_2O was lost but carried with it only small amounts of Na and Cl. Recent analyses of a trapped melt inclusion in an anorthoclase phenocryst from the Green Tuff has shown much less H_2O (1.5 wt %) but the same F (0.5 wt %). Analyses of inclusions in phenocrysts from more basic compositions on Pantelleria (hawaiite, aluminous trachyte, agpaitic trachyte) have not shown more than 0.2 wt % H_2O, but their F contents are surprisingly high (0.2, 0.3, and $\geq$1 wt %, respectively). Electron probe analyses for F give lower values, and we are working on resolving this discrepancy. However, the relative changes in F are consistent for both techniques.

The physical properties of silicate liquids are generally related to their chemical composition. Dissolved volatile components, in particular, can be extremely important in determining melting points, crystallization sequence and viscosity. Degassing of H_2O is expected upon eruption, but the pantellerites we have studied do not show a loss of F and only small depletion of Cl during this event. Scarfe (1977) measured the viscosity of a pantellerite, finding only a small decrease in fluidity (less than an order of magnitude) compared to metaluminous rhyolite. However, Dingwell et al. (1985) found that the viscosity of peralkaline melts could be greatly reduced when F was added (Cl also reduces viscosity but with less efficiency). Depending on the relation between halogen contents and viscosity, even though H_2O must be lost upon eruption, halogen-rich pantellerites may remain somewhat fluid. A complicating factor is the rapid crystallization of pantellerite upon loss of H_2O, although this should be checked on halogen-rich compositions. (Authors' abstract; references deleted).

KOVALISHIN, Z.I., VITYK, M.O. and SHAKUN, L.Z., 1988, Boiling as one mineral-forming mechanism at Beregovo Deposit: Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 52-53 (in Russian). First author at Inst. Geology and Geochemistry of Mineral Fuels of Acad. Sci. of Ukraine SSR, L'vov, Ukraine, U.S.S.R.

As concluded from inclusion studies in sphalerite and quartz, boiling of mineral-forming solutions and their mixing with surface waters are the main mechanisms of mineral precipitation at Beregovo deposit. Three boiling periods were found that are connected with the sulfide, quartz-barite and carbonate-quartz stages. The boiling was evidenced by the following observations: (1) presence of inclusions from heterogeneous trapping in gangue minerals; (2) decrease of the CO_2 content in fluid of the sulfide stage from the lower deposit horizons to the upper ones; (3) decrease of the SO_4/Cl ratio in the solution with the sampling depth [increase?—A.K.] observed at each stage; (4) slow total salt content increase in the solution versus its T decrease; and (5) extensive carbonate precipitation and quartz dissolution as boiling indices for the carbonate-quartz stage. Long continuous boiling led to the formation of a thick alunite-kaolinite-quartz zone in the upper horizons of this deposit. Evolution of the hydrothermal system of the deposit included the migration of the boiling level from lower to upper deposit horizons. (Author's abstract translated by A.K.)

KOZLOWSKI, A. and METZ, P., 1989a, Decrepitation: A genetic indicator or an ore prospecting tool? (abst.): Terra Abstracts, v. 1, p. 35. First author at Warsaw Univ., Poland.

The mechanism of the decrepitation of FI with various habits is briefly discussed and the relation between the Td and Th and Tt are presented. On this basis, and taking into account the other factors influencing Td like the size of inclusions, type of their filling, their position and abundance in a grain, the sample grain size etc., it is shown that practically Td can be directly related neither to Th nor to Tt. Examples are given which indicate that the mechanical distinguishing of the "inclusion generations" on a decrepigram as its peaks may be misleading and that one generation of inclusions may result in bi- or multimodal histogram of the Td versus the number of the inclusions decrepitated.

The following decrepitation techniques are described: acoustic, piezoelectric, gravimetric, visual, barometric (vacuum), gasometric, photometric and radiometric (radio wavelength). Attention is paid to the gas analysis results when gases were released from inclusions by decrepitation and possible errors caused by gas reactions at high-T are indicated. The examples show the practical usefulness and validity of the decrepitation method as a prospecting tool but not as a geothermometric method. (From authors' abstract)

KOZLOWSKI, A. and **METZ, P.**, 1989b, Comments on the decrepitation temperature method (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 59-60. Authors at Inst. Geochem., Mineral. & Petrogr., Fac. Geol., Warsaw Univ., Al. Zwirki I Wigury 93, 02.089 Warsaw, Poland.

Td of FI has been formerly used as a measure of the mineral formation T, but presently it is applied almost exclusively as an indicator of hydrothermal activity for mineral prospecting purposes. The results of the decrepitation runs are usually presented as a histogram of the number of decrepitated inclusions versus the Td, called a decrepitogram. The shape of the decrepitogram is supposed to yield important information, especially the number of modes in relation to the number of different inclusion types or generations in a sample (e.g., a bimodal decrepitogram would indicate the presence of two [different] inclusion generations, suggesting an activity of two different mineral-forming fluids).

Observations of inclusion decrepitation were performed on polished natural quartz plates using a new high-gradient, reflected light microscope heating stage. Two polished plates were made parallel to the "r" and "z" rhombohedron faces of a quartz crystal from Strzegom, Poland. The "r" plate contained a plane of the S inclusions 32 ± 6 μm in length, the "z" plate - a plane of the S inclusions 11 ± 4 μm in length. The measurements of *both* "r" and "z" inclusions (Th: 136 ± 4°C and salinity: 6.7 ± 0.2 wt % NaCl eq.) indicate formation from the *same* fluid. However, Td measurements for 446 "r" inclusions and 438 "z" inclusions resulted in a distinctly bimodal decrepitogram due to difference in the size of the inclusion.

Another quartz plate contained a wedge-shaped healed fracture with FI of Th 173 ± 2°C and salinity 5.3 ± 0.3 wt % NaCl eq. This single inclusion system gave a distinctly bimodal decrepitogram resulting from various inclusion numbers in different size classes (Fig. 1). (Authors' abstract)

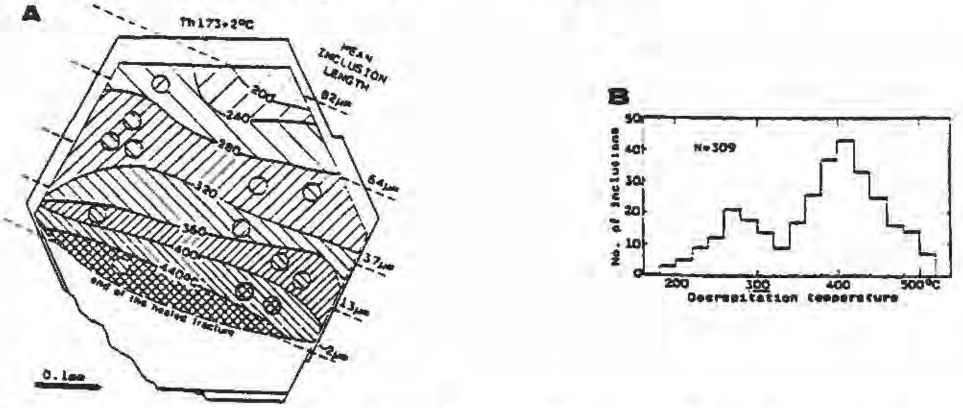


Figure 1. Quartz plate with heated, wedge-shaped fracture showing the Td distribution in the preparation is shown; B—the corresponding decrepitogram for this plate.

KOZLOWSKI, A. and **METZ, P.**, 1989c, Tourmaline aplite from lower Silesia: Three possible genetic models: Terra Abstracts, v. 1, 1989, p. 282-283. First author at Warsaw Univ., Warsaw, Poland.

The tourmaline aplite bodies investigated, range up to 2 m in thickness and probably several hundred meters in length. They occur within the roof of the metamorphic cover surrounding the Strzegom granitoid massif. The wall rocks consist of amphibolite (plagioclase ~An45, quartz, hornblende and minor sphene), graphite quartzite, and muscovite-biotite-quartz schist, with up to 5% kyanite. The aplite consists of (vol. %): 45-54 K-spar, 10-15 albite, 33-39 quartz, 2-5 schorl > dravite tourmaline, 0.5 biotite + muscovite + andalusite + sillimanite + almandine > spessartine garnet.

At present three modes of formation of this aplite are under consideration:

1. Intrusion of a peraluminous aplitic melt produced by degassing of "normal" granitic magma, enrichment of boron in the magma, and magmatic crystallization of all minerals, including garnet, andalusite and tourmaline (Puziewicz 1981).

2. Intrusion of a "normal" aplitic melt, contaminated by Al and B from the metamorphic wall rocks, and subsequent metasomatic crystallization of tourmaline at 450-360°C and 810-730 bar (FI data).

3. Origin of the whole "aplite" mineral assemblage due to metasomatic alteration of wall rocks by H_2O-CO_2-NaCl-type hydrothermal fluids.

The discussion of the rock genesis will also include consideration of the possible sources of CO_2 and B and the petrological importance of the andalusite, sillimanite and kyanite occurrence in the rocks investigated. (Authors' abstract)

KOZLOWSKI, A. and **METZ, P.**, 1989d, Contact-metasomatic paragenesis in the Garby Izerskie dislocation zone, Karkonosze-Izera block (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 101 (in English) (supplementary issue to European J. Mineral., v. 1.).

The SW-NE dislocation of Garby Izerskie, adjacent to the N margin of the Karkonosze (Riesengebirge) granitoid massif, is several km long. The mineralized zone connected with this dislocation occurs between the blastomylonitic gneisses at the NW side and the biotite-quartz hornfelses with andalusite and skarn intercalations at the SE side of the zone. The main stages of the mineral parageneses development in this area were as follows:

1. Regional metamorphism caused the origin of gneisses, chlorite-mica-quartz schists and fine-grained calc-silicate rocks; the dislocation developed.
2. The intruding Karkonosze granitoid mobilized silicifying fluids migrating along the dislocation to form a vein-like metasomatic quartz zone; the schists altered to hornfelses and the calc-silicate intercalations in coarse-grained quartz-wollastonite, diopside/hedenbergite-quartz-wollastonite, vesuvianite-wollastonite and grossular-vesuvianite-wollastonite-quartz skarns; Th of fluid inclusions in quartz is >430°C.
3. The quartz zone continued to develop laterally, passing into the gradually less silicified hornfelses and gneisses (Th 280-130°C); drusy euhedral quartz formed in cataclased parts (Th 280-140°C).
4. Granitoid apophyses intruded the fractures in the hornfelses and in the silicified zone.
5. The apophyses recrystallized locally during metasomatism to coarse-grained pegmatoid assemblages: microcline, albite, quartz, biotite, muscovite, tourmaline and hornblende, Th 360-230°C.
6. Early fluorine metasomatism resulted in formation of topaz in the apophyses.
7. Feldspars in apophyses altered to halloysite, and halloysite nests bearing euhedral rock crystals (Th 220-125°C formed in the massive quartz.
8. Hornfelses and apophyses were subjected to chloritization with the subsequent crystallization of pyrite, chalcopyrite and pyrrhotite.
9. Main fluorine metasomatism yielded fluorite-apophyllite-quartz (amethyst)-calcite paragenesis in skarns and fluorite elsewhere in the zone; Th of fluid inclusions in fluorite is 265-95°C.
10. Scarce torbernite-autunite mineralization developed in the silicified rocks. (Authors' abstract)

KOZLOWSKI, A. and **METZ, P.**, 1989e, Fluid inclusion studies in quartz from the reportedly gold-bearing veins from SW Poland, *in* Guan, Guangyue, ed., Proceedings of International Symposium on Gold Geology and Exploration (ISGGE), Shenyang, June 26-30, p. 731-735.

Two quartz veins in Lower Silesia, Poland, mined occasionally as Au ore in the past, were the object of the present investigation. Rare traces of native Au mineralization and of Au content in quartz, both exceeding the background values, have been found. Fluid inclusion studies have been performed to determine the conditions of vein quartz crystallization and to explore a possible occurrence of commercially exploitable Au mineralization.

The first vein near Szklarska Poreba occurs in the Karkonosze granitoid and consists of turbid amethyst, layers of milky quartz, nests of jasperoid and silicified relics of feldspars. Amethyst and milky quartz bear small P inclusions, up to 20 µm in length, with Th L-V(L) 150 to 220°C. The inclusions are filled by a water solution of Na and K chlorides having a total salt concentration of 8-15 wt % NaCl eq. as determined by the freezing method. Electron microprobe analysis of the inclusion leachate solution precipitate yielded the following composition (wt %): NaCl 57-70, KCl 26-40, $CaCl_2$ ~1, $MgCl_2$ ~1, $AlCl_3$ ~0.5, $FeCl_3$ ~0.5 and LiCl ~0.3 as determined by emission spectrography. Groups of CO_2-filled complex inclusions formed by homogeneous trapping have been found. They homogenize in the gas phase at +23.0 to +26.6°C, indicating a CO_2 density of 0.217 to 0.256 g/cm^3. The P, determined by Kalyuzhnyi's method, is ~200 bar at 200-220°C.

The second vein at Taczalin occurs in the so-called Wadroze Wielkie granite gneiss and consists of milky quartz. Disseminated kaolinite and sericite, as well as enclaves of clay minerals, are very common in this quartz. The fluid inclusions in the quartz have dimensions up to 25 μm and their genetic type (P or S) is difficult to determine. They have Th L-V(L) 180-230°C. The H_2O solution filling has a total salt concentration of 4-6 wt % NaCl eq., and the precipitate of the inclusion solution, as determined by electron microprobe method, has the following composition given (wt %): NaCl 50-61, KCl 37-48, $CaCl_2$ <0.2, $MgCl_2$ <0.2, $AlCl_3$ ~1, $FeCl_3$ ~0.7 and LiCl ~0.2 (measured by emission spectrography). Two types of CO_2-filled inclusions have been found: (1) complex inclusions of homogeneous trapping, Th L-V(V) +29.3 to +30.1°C (CO_2 density 0.313 to 0.336 g/cm^3) and (2) rare CO_2-filled inclusions of an unclear genetic position, Th L-V(L) +28.1 to +28.8°C. The P, determined as above, is 250-280 bar at 200-230°C.

The analysis of the obtained fluid inclusion data and its comparison with data published for commercial Au ore deposits suggest that the studied veins do not bear a Au mineralization of commercial value. The tenor of "ore" which can be expected is far below the limit appropriate for exploitation. (Authors' abstract)

KRAFFT, Maurice and KELLER, Jörg, 1989, Temperature measurements in carbonatite lava lakes and flows from Oldoinyo Lengai, Tanzania: Science, v. 245, p. 168-170. First author at Centre Vulcain, F-6700 Cernay, France.

The petrogenesis of carbonatites has important implications for mantle processes and for the magmatic evolution of mantle melts rich in CO_2. Oldoinyo Lengai, Tanzania, is the only active carbonatite volcano on Earth. Its high alkalic, Na-rich lava, although different in composition from the more common Ca-rich carbonatites, provides the opportunity for observations of the physical characteristics of carbonatite melts. T measurements on active carbonatitic lava flows and from carbonatitic lava lakes were carried out during a period of effusive activity in June 1988. T ranges from 491° to 519°C. The highest T, measured from a carbonatitic lava lake, was 544°C. These T are several hundred degrees lower than measurements from any silicate lava. At the observed T, the carbonatite melt had lower viscosities than the most fluid basaltic lavas. The unusually low magmatic T were confirmed with 1-atmosphere melting experiments on natural samples. (Authors' abstract)

KRESS, V.C., WILLIAMS, Quentin and CARMICHAEL, I.S.E., 1989, When is a silicate melt not a liquid?: Geochim. Cosmochim. Acta, v. 53, p. 1687-1692. First author at Dept. Geol. and Geophys., Univ. California, Berkeley, CA 94720.

The results of this study support earlier assertions that relaxed longitudinal ultrasonic velocities provide an accurate means of determining the compressibility of silicate melts. The observed discrepancy between ultrasonically derived compressibilities and those derived from high-P falling-sphere experiments cannot be attributed to relaxation effects. (From authors' abstract by E.R.)

KRUZHANOV, V.S., 1988, Movement of liquid inclusions in crystals with color centers: Kristallografiya, v. 33, p. 1505-1508 (in Russian; translated in Sov. Phys. Crystallogr., v. 33, no. 6, p. 895-897, 1988 (pub. 1989)). Author at State Univ., Khar'kov.

The author has investigated the motion of liquid inclusions in colored single crystals of KCl. He finds that the color centers have an accelerating influence on the kinetics of motion of the inclusions. He observes periodic gas emission in the bulk of the moving inclusions. (Author's abstract)

KUEHN, C.A., 1989, Studies of disseminated gold deposits near Carlin, Nevada: Evidence for a deep geologic setting of ore formation: Ph.D. thesis, Pennsylvania State Univ.

The Carlin Au deposit occurs in the upper 175 m of the Siluro-Devonian Roberts Mtns. Formation in Eureka County, Nevada. Pre-, syn- and post-Au episodes are distinguished by (1) hydrocarbon maturation, (2) Au mineralization and alteration, and (3) subsequent oxidation. Mineralization post-dates Early Cretaceous dikes which cut zones of thermally mature petroleum residue. Pre-ore P-T conditions of 155±20°C and 0.6 to 1.4 kb are defined by coexisting saline aqueous and methane-rich fluid inclusions.

Main Gold Ore Stage (MGOS) alteration of pyrite-bearing unaltered calcareous carbonaceous argillaceous siltstones progresses from K-feldspar silt and calcite destruction, then dolomite dissolution, and finally illite conversion to dickite/kaolinite in intensely altered silicified zones near hydrothermal conduits. Au is generally associated with intermediate alteration zones of carbonate removal. Volume loss following carbonate removal creates apparent enrichments of Al, Fe, and K, but ratios to geochemically immobile Ti and/or Al show little change except major Ca, Mg, CO_2 and minor K loss, and SiO_2 gain. Silica deposition spatially associated with Au requires cooling by decompression or mixing of different T fluids.

MGOS fluids are acid from elevated CO_2 contents (5-10 mole %), and also contain appreciable H_2S, 3 ± 1 wt % NaCl and $\delta^{18}O(H_2O)$ values +15‰ to >+9‰. CO_2-exsolution occurs at 215 ± 30°C and 800 ± 400 bars during portions of MGOS time and constrains ore formation to minimum depths of 4.4 ± 2.2 km. Late Gold Ore Stage (LGOS) fluids are non-boiling and gas-poor with ≤1.5 wt % NaCl and $\delta^{18}O(H_2O)$ values ≤-4‰ to -3‰. As LGOS fluids flood the system, calcite $\delta^{18}O$ values shift from near whole-rocks at +12 ± 3‰ to 0 ± 1‰ in veinlets containing unoxidized As ± Sb-phases. Two separate fluids are required to explain the large $\delta^{18}O$ range in MGOS/LGOS calcite veinlets, jasperoids and associated quartz. One is isotopically evolved, gas-rich, moderately saline and contains Au and SiO_2, whereas the second is gas-poor, dilute and isotopically resembles unevolved meteoric water.

Gas-rich fluids may result from buried intrusions, contact aureoles, or deeper low-grade metamorphism. Deposition may occur in throttling zones where conditions change abruptly from lithostatic to hydrostatic. Alternatively, dilational zones along deep structures may trigger decompressional boiling of gas-rich MGOS-type fluids and actively draw LGOS-type fluids into geologic settings of probably fluid-mixing. (Author's abstract)

KULIKOV, I.V. and **BOYARSKAYA, R.V.**, 1989, Hydrosaline melts in inclusions in fluorite from the Tyrnyauz deposit: Izvestiya AN SSSR, seriya geologicheskaya, 1989, no. 9, p. 81-98 (in Russian, translated in Int'l Geol. Rev., v. 31, p. 1039-1054, 1989). Authors at Inst. Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, USSR Academy of Sciences, Moscow, U.S.S.R.

A combination of methods, including optics, x-ray, mass spectrometry and electron microscopy, revealed very large (0.1-1 mm) FI in fluorite from the lower levels of the Tyrnyauz Mo-W deposit in the North Caucasus. The inclusions consist of a viscous brine of Ca, Na and K chlorides with a pH of 3; a gas phase including methane, nitrogen, CO_2 and traces of H_2S and C_2H_4 [sic; C_2H_6 in text—E.R.]; and solid phases, mainly chlorides, carbonates, graphite, and silicates. It is concluded that the T of the mineralizing medium could not have been <650-800°C. (Authors' abstract)

KUMAR, Anil, 1989, Mixture densities and volumes of aqueous KCl-$MgCl_2$ up to ionic strength of 4.5 mol kg^{-1} and at 298.15 K: J. Chem. Eng. Data, v. 34, p. 87-89.

KURODA, Yoshimasu, MATSUO, Sadao and **YAMADA, Tetsuo**, 1988, Deuterium/hydrogen fractionation during dehydration of hornblende, mica and volcanic glass: Ganko 1988, v. 83, no. 3, p. 85-94 (in English).

KUTZ, K.B. and **SPRY, P.G.**, 1989, The genetic relationship between Upper Mississippi Valley district lead-zinc mineralization and minor base metal mineralization in Iowa, Wisconsin, and Illinois: Econ. Geol., v. 84, p. 2139-2154. Authors at Dept. Geological and Atmospheric Sciences, 253 Science I, Iowa State Univ., Ames, IA 50011.

Minor base metal occurrences are present in Paleozoic dolomites, and to a lesser extent, in slates and sandstones in a broad zone surrounding the main Upper Mississippi Valley Zn-Pb district in Iowa, Wisconsin, and Illinois. These occurrences are of interest because they may be remnants of fluid pathways of Upper Mississippi Valley Zn-Pb mineralization. Outlying base metal occurrences contain mainly pyrite, marcasite, sphalerite, galena, and calcite; they occur in a variety of forms including vertical veins, gash veins, disseminated breccias, vug linings, and paleokarst replacement bodies. Two paragenetic types of mineralization are evident; occurrences in which sulfides are generally early and calcite is late, and occurrences in which carbonate (either calcite or dolomite but predominantly calcite) is early and sulfides are generally late. Similarities exist among mineralogy, geologic setting, and some geochemical aspects of the main Upper Mississippi Valley district and outlying occurrences. However, paragenetic, fluid inclusion, and stable isotope data indicate major differences in the genetic history of the outlying occurrences.

Fluid inclusion Th for outlying sphalerite and calcite range from 37.8° to 115.8°C. These T are generally lower than those reported previously for these minerals from the main Upper Mississippi Valley deposits (46°-220°C). Although measured salinities for inclusions in sphalerite in outlying occurrences (15.6-23.8 eq. wt % NaCl) are similar to those for sphalerite from the main Upper Mississippi Valley district (19.6->23 eq. wt % NaCl), salinities for inclusions in calcite in outlying occurrences (5.1-18.1 eq. wt % NaCl) are considerably higher than those determined for calcite (4.8-5.1 eq. wt %) from the main Upper Mississippi Valley district. The $\delta^{34}S$ values for outlying sulfates range from 21 to 31‰ (CDT) and are similar to those of the main Upper Mississippi Valley district (22-36‰). Overall values of $\delta^{34}S$ for sulfides from outlying occurrences range from -22 to +36‰ and contrast to that obtained from "pitch and flat" deposits (6-30‰) and gash veins (~1‰) from the main Upper Mississippi Valley district. Although sulfides from this district formed from reduced connate water sulfate, the wide range in sulfur isotope data was caused by the ore-forming fluid reacting, to varying degrees, with isotopically light diagenetic pyrite. Values of $\delta^{13}C$ and $\delta^{18}O$ for outlying calcites (-9 to +5‰ (PDB), and 21-29‰ (SMOW), respectively) tend to be heavier than calcites from pitch and flat deposits in the main Upper Mississippi Valley district ($\delta^{13}C$ = -13 to -2‰; $\delta^{18}O$ = 17-23‰). The $\delta^{18}O$ values for fluid inclusions in outlying mineralization (-8 to +6‰) are similar to those obtained from the main Upper Mississippi Valley district mineralization (-5 to 6‰); however, δD values (-95 to -20‰) are lighter than values (-47 to +2‰) for the main district. These isotopic values support a connate seawater source for the mineralizing fluids from both areas. S, C and O isotope data suggest that some outlying mineralization was more strongly influenced by local diagenetic processes than by processes that formed the main Upper Mississippi Valley deposits. (Authors' abstract)

KUZNJETSOVA, S.V., GOSTYAJEVA, N.M. and BABININ, O.K., 1989, Recrystallization inclusions of melts in the apatite of the granites of the Novoukrainian Massif: Dopovidi Akad. Nauk, Ukrains'koyi RSR, Seriya B, Geologichni Khimichni Biologichni Nauki, 1989, (11), p. 6-7 (in Ukrainian).

KYLE, J.R., BOARDMAN, Sabine and SASSEN, Roger, 1989, Mississippi Valley type Zn-Pb-Ag sulfide mineralization in the Upper Jurassic Smackover Formation in the Central Gulf Coast (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A7. First author at Dept. Geological Sciences, Univ. Texas, Austin, TX 78713.

The Upper Jurassic Smackover Formation is a major hydrocarbon reservoir in the Central Gulf Coast and locally hosts significant sulfide concentrations. The Smackover limestones (ooid grainstones to organic-rich mudstones) are dolomitized in the western part of the region. Sulfides occur in complex replacement and pore-filling textures and are locally associated with stylolites. Current formation waters are ~100°C Na-Ca-Cl brines that locally contain commercial Br and elevated H_2S contents.

The #1 Teague well in Lafayette Co., Arkansas, intersects a particularly well mineralized upper Smackover limestone sequence and contains sulfides throughout the cored interval from 8362-8484 ft. The most intense mineralization occurs in ooid grainstones in the upper 35 ft. Locally stylolites are dilated and contain euhedral sulfide crystals, indicating that late-stage sulfide mineralization post-dates maximum burial and compaction. The minerals forming this late-stage assemblage are fine-grained tan sphalerite, galena, acanthite, chalcopyrite, pyrite, marcasite, dolomite, coarse-grained yellow-brown sphalerite, and calcite. The Ag content of the high Zn-Pb zones is generally low (<1 to 10 ppm); however, a local 1 ft acanthite-rich interval assays more than 1000 ppm. $\delta^{34}S$ of sulfides ranges from +8.9 to +16.6‰ (CDT), and ΔS_{sl-ga} values of 4.5 and 5.9‰ suggest equilibrium precipitation T of 100 ± 25°C. Fluid inclusion data for late-stage sphalerite indicate precipitation from Na-Ca-Cl brines between 90 and 105°C. Petroleum-filled inclusions in late-stage calcite homogenize over a T range of 82 to 117°C.

Smackover H_2S has a similar $\delta^{34}S$ range (+18 ± 2‰) to Late Jurassic seawater sulfate, suggesting that thermochemical reduction of reservoir sulfate is the source of H_2S for sulfide precipitation. Thermal maturity data for Smackover petroleum from this area indicate that the crude oils have been subjected to thermal cracking. These data support a genetic relationship between crude oil destruction, thermochemical sulfate reduction, and sulfide mineralization. (Authors' abstract)

KYLE, J.R. and **SASSEN, R.**, 1989, Relation of Mississippi Valley type Zn-Pb-Ag mineralization and petroleum in Upper Jurassic Smackover Formation, central Gulf Coast, USA (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-249. First author at Univ. Texas, Austin, TX.

Fluid inclusion data for coarse-grained sphalerite indicate precipitation from Na-Ca-Cl brines in a Th range of 90-105°C. Petroleum-filled inclusions also occur in late-stage calcite. $\delta^{34}S$ for sulfides range from +8.9 to +16.6% ‰ (CDT) [sic]; ΔSsl-ga values of 4.5 and 5.9% ‰ for two sphalerite-galena pairs indicate equilibrium precipitation T of 77 and 128°C, respectively. Smackover-hosted H_2S has approximately the same $\delta^{34}S$ range (+ 18 ± 2‰) as Late Jurassic seawater sulfate, suggesting that thermochemical reduction of reservoir sulfate is the source of the H_2S for sulfide mineralization (Orr, 1977). Textural evidence suggests that sulfide precipitation from metalliferous brines was initiated at sites of local sulfate reduction in the upper Smackover. (From authors' abstract by E.R.)

LACAZETTE, Alfred, 1989, Applications of linear elastic fracture mechanics to fluid inclusion research (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A357. Author at Dept. Geosciences, The Pennsylvania State Univ., University Park, PA 16802.

Linear elastic fracture mechanics quantitatively relates the driving stress of a fracture to the elastic modulus and fracture surface energy of the fractured material. The fundamental relationship for a tensile fracture is given by $K_I = Y\sigma c^{1/2}$ where Y is a geometric factor that is characteristic of the crack shape, σ is the driving stress, and c is the crack half-length. K_I is the Mode I (opening mode) stress intensity factor. When a fracture is in equilibrium and is neither propagating or closing up, then $K_I = K_{IC}$, where K_{IC} is the critical stress intensity factor or fracture toughness, a material property derivable from the Young's modulus (E) and fracture surface energy (γ) of the material. Values of K_{IC}, E and γ are available for many minerals and for a range of representative rock types.

Because far-field stresses in the earth are almost invariably compressive, geologic fractures such as joints and Mode I veins propagate under conditions of local effective tension where the fracture driving stress is supplied by fluid P in the fracture. Fluid P estimates derived from fluid inclusions in syntectonic vein fillings may re related to earth stress via fracture mechanics. Fluid inclusions can therefore serve as paleostress meters. An example of this technique will be presented from the central Pennsylvania fold-thrust belt where methane-water thermobarometry has been used to directly measure the burial depth of the Bald Eagle Formation and the geothermal gradient at the onset of Alleghanian deformation.

Fracture mechanics may also be applied to understanding the decrepitation of fluid inclusions because the driving stress of the fracture that develops during decrepitation is equivalent to the internal P of the inclusion. Conversely, the decrepitation behavior of synthetic fluid inclusions can be used to provide direct and accurate measurements of the fracture surface energy of minerals under varying conditions of T and chemical environment because E is accurately known for most minerals. (Author's abstract)

LAL, D., CRAIG, H., WACKER, J.F. and **POREDA, R.**, 1989, ^3He in diamonds: The cosmogenic component: Geochimica Cosmochim. Acta, v. 53, p. 569-574. Authors at Scripps Inst. Oceanography, Univ. California, San Diego, La Jolla, CA 92093, USA.

We have measured ^3He and ^4He concentrations in a number of diamonds received directly from mines as well as in industrial samples. None of our diamonds recovered from underground mining has a $^3He/^4He$ ratio, R, exceeding 3 R_A (R_A = atmospheric $^3He/^4He$ ratio = $1.40 \bullet 10^{-6}$). One of the five diamonds from the Consolidated Diamond mine (CDM-5; an alluvial deposit) has a ratio of 142 R_A. Based on a number of facts: (i) the Zaire alluvial diamonds have >29% cosmogenic ^3He; (ii) some documented high $^3He/^4He$ ratio diamonds are from alluvial mines, and (iii) the apparent diffusion coefficients of ^3He and ^4He in diamonds are ten orders of magnitude too large to preserve diamond helium ratios in the mantle, we conclude that Ozima's hypothesis (Ozima et al., 1983) of high primordial $^3He/^4He$ ratios in diamonds exceeding MORB ratios is not required. The present data are readily explainable as the result of cosmogenic and nucleogenic production of ^3He within the diamonds. (Authors' abstract)

LANDAIS, P., 1989, Efficiency of organic matter as recorder of ore deposits history (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-256-257.

LANDAIS, P. and **MEYER, A.J.**, 1989, Temperature evolution assessment and indirect dating of mineralizations in a sedimentary ore deposit: Organic matter, fluid inclusions, fission track, and computer modeling (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-256. Authors at Centre de Recherches sur la Géologie de l'Uranium and GS CNRS-CREGU, Vandoeuvre lès Nancy, France.

New computer programs, especially designed to model the kinetics of organic matter evolution and hydrocarbon genesis can now be applied in the field of ore deposits. Time-independent data deduced from the study of fluid inclusions provide sets of punctual temperatures but rarely supply information concerning the time and duration of the fluids activity.

Apatite fission track ages give a measure of the time over which spontaneous tracks of uranium are formed and quantitatively stored in these minerals. Maximum temperatures responsible for the partial fading of the track density can be deduced from experimental annealing studies.

The combined use of those three geothermometers can be carried out when apatite-rich sandstones and organic bearing levels are located in the same geological context. Furthermore, fluid inclusions should be analyzed in several authigenic minerals distributed in the paragenetic sequence.

The breccia pipes from the Grand Canyon region (Arizona, USA) result from a solution collapse within the Mississippian Redwall limestone and stoping of the overlying strata. The brecciated Pennsylvanian and Permian rocks host U and Cu mineralizations that are presently mined.

Microthermometric analysis of fluid inclusions—indicating corrected Tt below 140°C—as well as geological information have led us to select a 50 Ma long thermal event. The corresponding integrated T respectively average 137°C (a) and 129°C (b). These two thermal histories have been introduced in the computer model to calculate the maturation state of organic matter in terms of T_{max}. Results respectively indicate computer T_{max} of 445°C (a) and 430°C (b), which fall in the range of observed T_{max} of the Toroweap (Permian) kerogens (424-432°C). Then the calculated thermal histories fit with the observed maturity parameters of organic matter. (From authors' abstract by E.R.)

LANDAIS, P., MEYER, A., CARISEY, J.C., KREWEDL, K.A., BROSSE, E. and **FORBES, P.**, 1989, Geothermal analyses of the breccia pipes (Arizona); organic matter, fluid inclusions, fission tracks and computerized modeling (abst.), *in* E. Muller-Kahle, ed., Uranium resources and geology of North America: Proc. technical committee meeting on uranium resources and geology of North America, Saskatoon, SK, Sept. 1-3, 1987, Int'l Atomic Energy Agency, Div. Nucl. Fuel cycle, Vienna, Austria, IAEA-Tecdoc, p. 239.

LANDIS, G.P. and **RYE, R.O.**, 1989, Reconnaissance gas chemistry of the Creede, Colorado, hydrothermal system: U.S. Geol. Surv. Open-File Report 89-84, 51 pp. Authors at U.S. Geol. Surv., MS 963, Denver Federal Center, Denver, CO 80225.

The gas chemistry (H_2O, CO_2, H_2S, SO_2, Ar, N_2, CH_4, and various organic species) of the Creede hydrothermal fluids was determined from inclusion fluids in samples representative of the time-space features of the hydrothermal system as indicated by previous stable isotope studies of the fluids and host minerals. In addition, gas chemistry studies were made on samples that have been the subject of detailed fluid inclusion T and salinity studies. The gas chemistry of the Creede hydrothermal system was highly variable in time and space. The gas compositions are significant indicators of the sources and evolution of fluids in the veins and at depth. Each major stage of mineralization is characterized by a specific gas chemistry which may have been modified locally by mixing and/or boiling. The gas compositions of fluids derived from the highlands in the northern part of the district are distinct from fluids derived from the sediments in the moat of the Creede caldera in the south. Fluids from all paragenetic stages, including those from the high-T (up to 310°C) and high fO_2 (hematite stable) main stages, contain a complex (and as yet poorly-characterized) mixture of alkanes, alkenes, and aromatic hydrocarbons. These hydrocarbons must have been derived from progressive thermal degradation or pyrolysis of moat sediment organic matter in the southern part of the district and from a hidden source of saturated hydrocarbons in the northern part of the district. The presence of significant quantities of SO_2 in some of the fluids suggests the formation of metastable thiosulfate during mixing of the hydrothermal fluids with low pH fluids in the overlying groundwater. The persistence of the organic species and disequilibrium gas compositions in the fluids both indicate lack of attainment of complete chemical equilibrium in the system consistent with interpretations based on the chemical and sulfur isotope composition of ore minerals.

To obtain these gas chemistry data, samples were heated in a vacuum furnace with a programmed T rise. Computerized, real-time multiple ion monitoring on the gases released was performed by quadrupole mass spectrometer. Thermal gas release profiles define discrete populations of fluid inclusions that can be distinguished from adsorbed/desorbed gas release, the thermal decomposition of host minerals and occult solid inclusions, and "matrix gas" released from submicron-sized fluid inclusions, domain boundaries, micro-structures, crystal defects, and gas dissolved in the crystal. Possible gas reactions and pyrolysis during decrepitation are evident from product and reactant profiles. Superimposed upon the thermal profiles are sharply-defined spikes that represent sudden release of gas from single or multiple fluid inclusions. Quantitative analysis of these "bursts" permits detailed study of ore fluid chemistry at the level of individual fluid inclusions. Gas partial P were determined from the mass spectrometer data with gas-specific correction factors that include the ion sensitivity and fragmentation, kinetic rates of adsorption/desorption on vacuum surfaces, and differential vacuum pumping. (Authors' abstract)

This is a "reformatted and greatly amplified version" of a 1987 presentation (Landis and Rye, 1987, Fluid Inclusion Research, v. 20, p. 222-223). (E.R.)

LANDIS, G.P. and **TSCHAUDER, R.J.**, 1988, Paleokarst-controlled ore in central Colorado, *in* T.B. Thompson et al., eds., Geology and Mineralization of the Gilman-Leadville area, Colorado, in the collection Guidebook series of the Society of Economic Geologists: Soc. Econ. Geol. 2, 1988, p. 100-104.

Indexed under FI. (E.R.)

LANDOLL, J.D., FOLAND, K.A. and **HENDERSON, C.M.B.**, 1989, Excess argon in amphiboles from fluid interaction and short intrusion interval at the epizonal Marangudzi complex, Zimbabwe: J. Geophys. Res., v. 94, no. B4, p. 4053-4069. First author at Dept. Geol. and Min., Ohio State Univ., Columbus, OH.

Excess Ar is restricted to amphiboles displaying substantial Fe/Mg zoning which is interpreted as reflecting late magmatic or early sub-solidus reaction with fluid phases. Ar was apparently acquired from the fluid during alteration and ultimately, could have been magmatic or could have come from degassing of the country rocks. (From authors' abstract by E.R.)

LANE, Tom, 1989, Sphalerite/dolomite stratigraphy and the tectonic origin of an MVT deposit, Daniel's Harbour, western Newfoundland, Canada (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A8. Author at Dept. Earth Sciences, Memorial Univ. of Newfoundland, St. John's, Newfoundland A1B 3X5, Canada.

An MVT-zinc deposit at Newfoundland Zinc Mines occurs in dolostone complexes of Lower Ordovician platformal carbonates of the upper St. George Group. Like some other MVT deposits it is intimately associated with karst breccias beneath a regional unconformity. Detailed sphalerite/dolomite stratigraphy and structural relationships, however, indicate a deep burial/tectonic origin for the deposit. Several generations of breccias associated with two stages of sulphide deposition and three periods of dolomitization record a protracted history of fracturing and faulting under a regime of regional compression during early phases of the Middle Paleozoic Acadian Orogeny.

Coarse, ore-stage dolostone/sphalerite bodies, including stratabound pseudobreccias and fracture-related breccias, overprint both limestones and early diagenetic dolostones. These coarse bodies envelope linear, stratabound vein systems which surround early dolomitized karst breccias and steep faults. They developed in four stages: (1) pervasive pre-ore dolomitization (I) of limestones along fractures; (2) fracturing and partial dissolution of these dolostones (I); (3) two episodes of sulphide precipitation separated by fracturing and brecciation; and (4) extensive replacement of pre-ore dolostones (I) and pore-filling by saddle dolomite (II and III) in association with late fracturing and brecciation. Hypersaline (25 eq. wt % NaCl), hydrothermal (Th = 90 to 185°C) inclusion fluids originated from a deep source area. Moreover, the presence of contemporaneous stylolites, evidence of elevated fluid P and reconstructed overburden estimates of more than 1000 m also imply burial conditions at the site of ore deposition. Rotated geopetal sediments in ore-stage cavities and displaced ore bodies along faults demonstrate that regional thrusting and uplift at the climax of the Acadian Orogeny post-dated ore deposition. (Author's abstract)

LANG, J.R., GUAN, Yin and EASTOE, C.J., 1989, Stable isotope studies of sulfates and sulfides in the Mineral Park porphyry Cu-Mo system, Arizona: Econ. Geol., v. 84, p. 650-662. First author at Dept. Geosciences, Univ. Arizona, Tucson, AZ 85721.

Sulfide minerals from five vein stages in and near Mineral Park have a shared $\delta^{34}S$ range of 0 to 5‰ (47 values). Anhydrites from anhydrite-molybdenite and anhydrite-chalcopyrite vein stages have nearly identical $\delta^{34}S$ ranges of 12.6 to 22.7‰ No spatial isotopic zonation is evident. In the anhydrite-molybdenite vein stage, a $\delta^{34}S$ versus $\Delta^{34}S$ plot for anhydrite-pyrite pairs suggests an H_2S-dominated fluid and a bulk fluid $\delta^{34}S$ value near 1‰, but general isotopic disequilibrium is suspected. In the anhydrite-chalcopyrite vein stage, mineral relationships indicate a sulfate-dominated hydrothermal fluid. Isotopic T from anhydrite-pyrite pairs of this stage generally match fluid inclusion data [from Lang et al., 1987, Fluid Inclusion Research, v. 20, p. 224] in veins from felsic hosts but are more dispersed in veins from mafic hosts. This may reflect local isotopic disequilibrium resulting from reduction of sulfate by ferrous silicates in the mafic hosts. Use of the $\delta^{34}S$ versus $\Delta^{34}S$ plot, which indicated different values for the sulfate/sulfide ratio and bulk fluid $\delta^{34}S$ for mafic- and felsic-hosted data subsets, is thus compromised. The fluid that deposited late polymetallic quartz veins appears to have been H_2S dominated, with a bulk fluid $\delta^{34}S$ value of 2 to 4‰. The isotopic data are not sufficient to discriminate among potential sources for the hydrothermal sulfur.

Oxygen isotope data on anhydrites indicate that two distinct generations were deposited. The data are compatible with a mixed magmatic-meteoric origin for waters (calculated $\delta^{18}O_{water}$ range, 6.5-9.2‰) that deposited anhydrite-molybdenite veins, and with either a magmatic or an evaporitic origin for the waters (calculated $\delta^{18}O_{water}$ range, 11.8-17.1‰) that deposited anhydrite-chalcopyrite veins. Magmatic sources for the fluids that deposited anhydrite are the most compatible with geologic and fluid inclusion data. (Authors' abstract)

LANGER, J.S., 1989, Dendrites, viscous fingers, and the theory of pattern formation: Science, v. 243, p. 1150-1156. Author at Inst. Theoretical Physics, Univ. California, Santa Barbara, CA 93106.

There has emerged recently a new theoretical picture of the way in which patterns are formed in dendritic crystal growth and in the closely analogous phenomenon of viscous fingering in fluids. Some interesting questions that arise in connection with this theory include: How broad is its range of validity? How do we understand dynamic stability in systems of this kind? What is the origin of sidebranches? Can weak noise, or even microscopic thermal fluctuations, play a role in determining the macroscopic features of these systems? (Author's abstract)

LAO, Kheang, TRUDEL, Pierre, GAULIN, Raymond and PERRAULT, Guy, 1989, Thermal variation in early to late quartz at the Elder gold mine, Noranda, NW Quebec (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-92. Authors at Dépt. de génie min. and IREM/MERI, Ecole Polytech., Montreal, Quebec H3C 3A7, Canada.

Two types of quartz are recognized in three subparallel veins (1, 3 and 5) related to the Au mineralization at the Elder mine: the most abundant early quartz (70 to 90%) and the less abundant late quartz (<30%). In both types of quartz, FI are distinguished into three species: aqueous, carbonic and aquacarbonic inclusions. In all three veins, the H_2O-CO_2 inclusions are the most abundant. From the melting T of -56.6°C, the CO_2-phase in all types of inclusions is pure. The aqueous solution was undersaturated with NaCl and the salinity deduced from the H_2O-inclusions is: 10 wt % eq. NaCl for vein 1, 8.5 wt % for vein 3 and 15 wt % for vein 5; there is not significant difference in salinity between early and late quartz in each vein.

Thermal conditions deduced for the H_2O and CO_2 inclusions show that the early quartz in all veins was formed at T between 150° and 200° and the late quartz between 250° and 300°C. Chemical analyses of inclusion residues show that the fluids in all veins have an average Na/(Na + K) wt ratio of 0.95. The fluid in vein 5 is a chloride type (Cl/(Na + K) >1.36 and S/(Na + K) <0.20) while that in veins 1 and 3 contains more S than Cl (S/(Na + K) >0.40 and Cl/(Na + K) <0.10).

In conclusion, the above data suggest that the early quartz and the late quartz in each vein at Elder were formed from the same type of fluid but at different T. (Authors' abstract)

LAPORTE, D. and WATSON, E.B., 1989a, Melt distribution in crustal sources (abst.): Eos, v. 70, p. 499. Authors at Dept. Geol., Rensselaer Polytech. Inst., Troy, NY 12180.

The grain-scale distribution of liquid in partially-molten rocks is governed by the principle of interfacial energy minimization.

Crustal lithologies depart significantly from the ideal. A realistic model of the melt distribution in the crust should include [various] additional elements. A better understanding of the processes by which acid to intermediate melts are segregated in magmatic bodies cannot be reached without due consideration to the melt distribution in crustal sources. (From authors' abstract)

LAPORTE, D. and **WATSON, E.B.,** 1989b, Wetting behaviour of H_2O-CO_2-NaCl fluids in quartzites under crustal conditions (abst.): Eos, v. 70, p. 1406.

LARSEN, R.B., 1989, Evolution of the fluid phase in regional tungsten skarn from the Norwegian Caledonides: A fluid inclusion study (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A286-287. Author at Inst. Petrology, Copenhagen Univ., Oestervoldgade 10, 2150 Copenhagen K, Denmark.

An example of regional W skarn has been recognized in the northern part of the Norwegian Caledonides. The mineralizations are hosted in Eocambrian metasedimentary rocks partly covering a Precambrian window with a 1731 m.y. old quartz monzonitic gneiss. The rocks attained their present configuration during the Caledonian orogenesis in Devonian Silurian time.

The skarn mineralizations formed in the metasedimentary sequence above the quartz monzonitic gneiss and are stratabound or confined to subconcordant fissures that can be followed for a distance of at least 6 km.

The mineralizations are classified as a scapolite (Me_{70}) scheelite ($CaWO_4$) type infiltration skarn developed by replacement of marble, felsic hornblende gneiss and schist. The fluid conduits are represented by quartz-plagioclase filled fissures and cavities and a plagioclase-quartz-scheelite vein type skarn.

Fluid inclusion studies revealed that both scapolite, plagioclase and scheelite host P CO_2 inclusions with 2 to 17 mole % CH_4. Isochoric considerations combined with equilibrium calculations on solid species indicate that scapolite and plagioclase nucleated in the host rock before wolfram complexes reacted with calcic minerals and precipitated scheelite.

The W skarn is a possible example of mineralization that to some extent has developed because of metamorphic processes terminating regional metamorphism at the end of the Caledonian orogenesis. (Author's abstract)

LATTANZI, P., 1989, The nature of the fluids associated with the Monte Rosa gold district, NW Alps, Italy (abst.): Terra abstracts, v. 1, p. 26.

Recent O-isotope and fluid inclusion studies, coupled with geological and mineralogical data, have provided evidence on the nature of the fluids associated with the late-Alpine quartz-Au vein-like deposits of the Monte Rosa Au district.

The most abundant inclusions in quartz from these deposits contain a moderately saline brine (~2 to 10 % wt NaCl eq.), and a CO_2 phase (usually <20 % mol), in places with minor methane. CO_2 densities and total Th vary widely throughout the district, reflecting diverse conditions of trapping (P = 1 to 3 kb, T = 300 to 450°C). A second type of inclusion contains an aqueous brine without recognizable CO_2 and is especially abundant at Val Toppa. O-isotope data suggest that fluids were largely equilibrated in a metamorphic environment. Late-Alpine metamorphic devolatilization reactions were the likely main source of fluids in the district; at Val Toppa, both isotopic and fluid inclusion data point to contributions of meteoric waters.

Mechanisms of Au transport and precipitation are less constrained. A possible model involves transport of Au as bisulfide complex and precipitation due to one or more of the following mechanisms: wall-rock reaction, decrease of sulfur activity due to precipitation of sulfides, cooling, dilution. (Author's abstract)

LATTANZI, P., CORAZZA, M., CORSINI, F. and **TANELLI, G.,** 1989, Sulfide mineralogy in the polymetallic cassiterite deposits of Dachang, P. R. China: Mineral. Deposita, v. 24, p. 141-147. First author at Dipartimento di Scienze della Terra, Università di Firenze, via G. La Pira 4, I-50121 Firenze, Italy.

Several important mineral deposits of Sn, Zn, Cu, Pb, and other metals associated with Devonian sediments and Yanshanian (Cretaceous) granitic rocks are known in the Dachang district (Guangxi). Early genetic hypotheses related the origin of the deposits entirely to the Yanshanian granites. Recently, it was suggested that in Devonian times an earlier syngenetic metal concentration may have occurred, later overprinted by the Yanshanian metallogeny. The sulfide chemistry (arsenopyrite, sphalerite, stannite) and FI data on the two major deposits in the area, i.e., the polymetallic cassiterite deposit of Changpo and the Zn-Cu skarn deposit of Lamo have been studied.

Lamo fluorite shows salinities of ~0-9.5 eq. wt % NaCl, and Th between 160°C and 250°C; quartz, moderate salinities (~0-4.6 eq. wt % NaCl), and Th of 208°-260°C. The evidence suggests that the P was relatively low (on the order of 1-1.5 kb); T may have been as high as 500°C during deposition of the As-richest arsenopyrites, but eventually dropped <200°-250°C in the latest stages. (From authors' abstract by E.R.)

LATTANZI, P.F., CURTI, Enzo and BASTOGI, Marco, 1989, Fluid inclusion studies on the gold deposits of the upper Anzasca Valley, northwestern Alps, Italy: Econ. Geol., v. 84, p. 1382-1397. First author at Dipartimento di Scienze della Terra, Universitá di Firenze, via G. La Pira 4, I-50121 Firenze, Italy.

The Au deposits of the upper Anzasca Valley are part of the Monte Rosa Au district, northwestern Alps, Italy. The mineralization occurs within polymetamorphic Paleozoic metasedimentary and metagranitic rocks of the Pennidic Monte Rosa unit. The mineralogy of the orebodies is dominated by quartz. Au is invariably associated with sulfides (pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, and sulfosalts).

The characteristics of fluid inclusions in quartz from Au-bearing veins are remarkably consistent: the inclusions are moderately saline brines containing, at room T, ~20 to 60% vol of a low-density, rather pure CO_2 phase; they were probably homogeneous at the time of trapping. Small amounts of CH_4 occur in some inclusions. Total homogenization occurs either in the liquid or in the gas phase, or by near-critical phenomena, at T mostly ~300° to 350°C. By combining these T with geologic P estimates and with T inferred from arsenopyrite compositions, trapping conditions of about 400° to 450°C at pressures of 1 to 1.5 kbars are derived. A less common, presumably later, type of CO_2-poor inclusion is interpreted as a late influx of cooler and less saline fluids.

Quartz from barren veins also contains CO_2-bearing inclusions; however, these show higher Tm(clathrate), lower Th(CO_2), and lower total Th than mineralized veins.

Results of reconnaissance studies of fluid inclusions from other Au deposits (Val Sesia, Val Toppa) in the Monte Rosa district are somewhat different from those of the upper Anzasca Valley: The CO_2 phase is of higher density, and total Th are lower.

Combined with field evidence and available Pb and O isotope data, the fluid inclusion characteristics are consistent with a model of ore genesis in which the Au deposits of the upper Anzasca Valley were formed in the late stages of the Alpine orogeny by presumably metamorphic fluids, probably produced by devolatilization of deep unexposed portions of Monte Rosa crustal rocks. The strict association of Au with sulfides suggests that Au possibly was transported as thio complexes. Possible precipitation mechanisms include cooling, dilution, minor wall-rock reaction, and decrease of sulfur activity in the fluid. Similar processes probably were active in the formation of other neighboring Au deposits, but there is evidence that Au deposition, on a regional scale, was related to at least two distinct hydrothermal systems separate in space and also in time. (Authors' abstract)

LAUBACH, S.E., 1989, Paleostress directions from the preferred orientation of closed microfractures (fluid-inclusion planes) in sandstone, East Texas basin, U.S.A.: J. Struct. Geol., v. 11, no. 5, p. 603-611. Author at Bureau of Economic Geology, The Univ. Texas at Austin, Austin, TX 78713-7508.

Closed extensional microfractures are useful indicators of paleostress directions in shallowly buried quartz-cemented quartz-arenites of the Lower Cretaceous Travis Peak Formation, a tabular sandstone and shale unit ~670 m thick that was deposited in the gradually subsiding northern Gulf of Mexico basin. The closed microfractures are syndiagenetic FI-rich planes that have an ENE strike that is subparallel to contemporary quartz-filled extension veins and regional normal faults, indicating that closed microfractures contain the maximum paleostress direction. These microstructures are potentially useful for mapping paleostress trajectories in passive margin and platform settings, particularly where samples are obtained from core. Previous experimental studies of microfracture closure suggest that microfractures evolved into FI planes by dendritic quartz precipitation. In East Texas, microfracture closure may have occurred at T as low as 85°C and depths as shallow as 1500 m. (From author's abstract)

LAUBACH, S.E. and **BOARDMAN, S.,** 1989, Multiple generations of fluid inclusions in Cretaceous quartz veins from the Gulf of Mexico basin (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A64. Authors at Bureau of Economic Geology, Univ. Texas at Austin, Univ. Station, Austin, TX 78713.

Quartz veins with complex arrays of fluid inclusions formed during thermal subsidence of the Gulf of Mexico passive margin basin in sandstone of the Lower Cretaceous Travis Peak Formation. Inclusions indicate that two fluids of contrasting salinity and T migrated through the fractures at different times. Crack-seal vein growth during quartz precipitation created the first generation of fluid inclusions (Vf_1), which are in evenly spaced planes parallel to subvertical vein margins. SEM observations show that these planes are composed of layers of closely spaced, small (<0.25 μm) equant P inclusions interspersed with massive quartz layers containing planes of large (0.5 to 10 μm) Vf_1 inclusions having spherical or negative crystal shape. Sparse Th data from these early inclusions suggest veins formed in the presence of warm (~100°C) brine (5 to 10 wt % NaCl eq.). However, contamination by younger fluids and inclusion stretching may cause Th to be an overestimate of Tt. For water T ~100°C, the $\delta^{18}O$ vein quartz composition of +21 to 22‰ (SMOW) is consistent with precipitation from a fluid with a $\delta^{18}O$ composition of -2‰. Synkinematic quartz (Q^1) with Vf_1 inclusions is overprinted by rims of fluid-inclusion-free postkinematic quartz (Q^2), postkinematic ankerite, and a small amount of late quartz (Q^3). Carbonate inclusions have Th of 157 to 178°C. A second inclusion generation in quartz, Vf_2, occurs as S planes that crosscut both Vf_1-bearing quartz and postkinematic quartz. Vf_2 planes are subvertical, but they are not parallel or regularly spaced, and most inclusions show evidence of necking. Inclusions are elongate to irregular with maximum length ranging from <1 to >10 μm. Th for Vf_2 inclusions ranges from 120 to 170°C, with a mean of 150°C. Mean salinity is 11 wt % NaCl eq., but values range from 5 to >20 wt % NaCl eq. The T range and variable salinity of Vf_2 inclusions could have been caused by mixing of two fluids of different salinities during trapping of Vf_2. (Authors' abstract)

LAW, B.E., NUCCIO, V.F. and **BARKER, C.E.,** 1989, Kinky vitrinite reflectance well profiles: Evidence of paleopore pressure in low-permeability, gas-bearing sequences in Rocky Mountain foreland basins: Am. Assoc. Petrol. Geol. Bull., v. 73, no. 8, p. 999-1010.

LAYNE, G.D., 1988, The JC tin skarn, southern Yukon Territory: A mineralogical, fluid inclusion and stable isotope study: Dissertation, Univ. Toronto, Toronto, Ontario, Canada. (Diss. Abstr. Int. B 1989, 49(11), 4720.)

See Fluid Inclusion Research, v. 21, p. 222 & 223. (E.R.)

LEA, D.W., LARSON, P.B., TAYLOR, H.P., Jr. and **CRAWFORD, M.L.,** 1989, Oxygen isotope and fluid inclusion study of the Mineral Point area, Eureka graben, Colorado: Econ. Geol., v. 84, p. 1656-1662. First author at Dept. Geological Sciences, Univ. California, Santa Barbara, Santa Barbara, CA 93106.

Th ranged from 199-273°C; Tm [ice?] ranged from -1.6 to +0.1°C. Sample Th varied with depth, suggesting thermal gradient of 0.05°C/m. No evidence for boiling was found. The fluids are typical of ^{18}O-shifted meteoric waters in the Late Tertiary. (E.R.)

LEACH, D., PLUMLEE, G., VIETS, J., HOFSTRA, A.A., ROWAN, L. and **LANDIS, G.,** 1989, Chemical modeling of Mississippi Valley-type depositional processes based upon quantitative fluid inclusion analyses (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A9. Authors at U.S. Geological Survey, MS 973, Federal Center, Denver, CO 80225.

The Ozark region of the USA hosts world-class Mississippi Valley-type (MVT) districts and regional occurrences of hydrothermal dolomite with traces of sulfides. Fluid inclusion solutes, determined by atomic absorption and ion chromatography, define two distinct end member compositions. Octahedral galena-stage fluids from the Viburnum Trend contain K of 0.20-0.29 m and Mg of 0.14-0.20 m. Cubic galena-stage fluids from the Viburnum Trend and from other MVT districts and occurrences have K of 0.08-0.11 m and Mg of 0.08-0.12 m. Calculated Cl concentrations of both end member fluids are identical, ranging from 4-6 m. Th range from 90-140°C and do not correlate with salinity. Quadrupole mass spectrometry of individual fluid inclusions shows that all samples contain both gas-dominant, CO_2-rich inclusions and H_2O-dominant inclusions. The CO_2-rich inclusions indicate the presence of a CO_2-rich gas phase during deposition of (1) regional dolomite cement and (2) more localized occurrences of ore. The

H_2O-dominant inclusions contain 0.62 mole % CO_2 and less than 0.3 mole % of H_2S, SO_2, N_2, CH_4 and C_nH_m. Fluids in sulfides contain more H_2S and CH_4 than those in associated quartz or dolomite.

Chemical speciation calculations indicate that dolomite-saturated brines had acidic pH values from 4.25 to 4.75. Calculated saturation P (120-200 bars) are consistent with hydrostatic P at the maximum stratigraphic depths estimated for the MVT districts (1.5-2 km). Reaction path models show that isothermal CO_2 effervescence during the migration of a single brine to shallower crustal levels could produce the regional occurrences of hydrothermal dolomite with traces of sulfides; however, this process could not produce the sulfide concentrations found in MVT ore deposits. Reaction paths modeling the mixing of two fluids, with various brine compositions, generally predict precipitation of sulfide-rich assemblages with less quartz than straight cooling paths. Thus, mixing of basinal brines in ore zones is the most viable mechanism for formation of MVT ore deposits. Mixing can account for the small amounts of quartz in the ores, the wide range in salinity, the systematic changes in K and Mg through the paragenesis, and the higher H_2S and CH_4 contents of inclusion fluids in sulfide minerals relative to quartz or dolomite. Acid produced during sulfide deposition could dissolve the host carbonates and cause CO_2 effervescence in the ore zones. (Authors' abstract)

LEBLANC, M. and BUISSON, G., 1989, Gold deposits related to carbonatized ultramafic rocks (listwaenites) (abst.): Terra abstracts, v. 1, p. 29.

Many gold deposits from Archean greenstone belts are in hydrothermally carbonatized ultramafic rocks. In Au-bearing listwaenites the average Au (1-10 ppm) is related to pyrite or arsenide-rich zones. Some major Au ore bodies of an apparently distinct type, such as the Mother Lode, are also related to hydrothermally carbonatized ultramafic rocks.

The carbonate lenses were formed by CO_2-Ca metasomatism during the late stages of serpentinization by boiling of CO_2-rich fluids (300-250°C) leaving an aqueous solution at 150°C.

Ultramafic rocks are a suitable Au source-rock: Au is efficiently mobilized during serpentinization and carbonatization; carbonatized ultramafic rocks are favorable reducing environments for Au precipitation. (From authors' abstract by E.R.)

LEE, V.W., MACKWELL, S.J. and BRANTLEY, S.L., 1989, Effect of fluid chemistry on the wetting of quartzite (abst.): Eos, v. 70, p. 502. Authors at Dept. Geosci., 403 Deike Bldg., Penn State Univ., University Park, PA 16802.

High P, hydrothermal experiments were carried out on samples of Arkansas novaculite in the presence of a number of fluid compositions in order to investigate the effect of fluid chemistry on the wetting of a dense, fine-grained quartz aggregate (grain size = 5 μm, porosity <1%). Prisms of the quartzite ($2x\ 2 \times 5\ mm^3$) and 50 μg of either pure H_2O, CO_2-H_2O, or an aqueous solution of selected salts (6 m NaCl, 4 m NaCl, 2 m $CaCl_2$, 1 m $CaCl_2$) were welded inside Ag-Pd capsules and reacted within an internally-heated P vessel at 600°C and 300 MPa for a duration of 6 hours. Only samples from capsules that contained fluid at the end of the experiments were subsequently investigated. The samples were cut in half, polished, and examined using the scanning electron microscope. Grain triple junctions were photographed and dihedral angles, θ were measured. The criterion for wetting is $\theta < 60°$.

Preliminary experimental results indicate that this fine-grained quartzite is wet by certain fluid chemistries and that there is a correlation between solute chemistry and the developed dihedral angle, θ. The dihedral angles for the 6 m NaCl and 4 m NaCl experiments are $40° \pm 9°$ and $41° \pm 14°$, respectively; few non-wetting grain triple junctions were observed. The 2 m $CaCl_2$ and 1 m $CaCl_2$ experiments displayed limited wetting, with comparatively fewer wetting triple junctions and with consistently larger dihedral angles than for the NaCl solutions. Additionally, the samples treated in $CaCl_2$ solutions were significantly more coherent than those treated in NaCl solutions, further indicating less wetting behavior. The CO_2-H_2O and the pure H_2O experiments were non-wetting; no wetting triple junctions were observed for either sample ($\theta > 60°$).

Further experiments are in progress to measure dihedral angles for more dilute solute concentrations, to test the wetting behavior of other aqueous salt solutions and to investigate the kinetics of wetting. (Authors' abstract)

LEEDER, O., KUMANN, R., BINDE, G., SELTMANN, R. and WIRTH, C., 1987, Formational and paragenetic characterization of tin deposits under specially consideration of fluid inclusions: Freiberger Forsch., C423, 1987, p. 35-61 (in German).

LEITCH, C.H.B., 1989, Geology, wall rock alteration, and characteristics of the ore fluid at the Bralorne mesothermal gold vein deposit, southwestern British Columbia: PhD dissertation, Univ. Brit. Col.

The Bralorne-Pioneer deposit produced more Au than any other deposit in British Columbia over its 70 years of operation (130 tonnes or 4 million oz of Au, from 7 million tonnes of 18 g/t ore).

Based on FI and stable isotope studies, primary ore deposition appears to have been from fluids of low salinity (<5 wt % NaCl eq.) with a significant CO_2 and minor CH_4 content, at 350°C and P of up to 1.75 kb (7 km depth). Computer modelling of the ore fluid suggests it had a pH of ~4.5, a Na:K ratio of at least 8:1, and a high content of dissolved CO_2 (log fugacity +2.5). Conditions were strongly reducing, as suggested by the CH_4 (log fugacity +0.5), with fO_2 about 10^{-30} and fS_2 about 10^{-7}. The model predicts precipitation of Au in response to reaction with the adjacent, highly altered wall rock, and a strong correlation between Au and pyrite, but not with pyrrhotite. (From author's abstract by E.R.)

LEITCH, C.H.B., GODWIN, C.I., BROWN, T.H., TAYLOR, B.E. and **CORNELL, W.C.**, 1989, Characteristics of mineralizing fluids in the Bralorne-Pioneer mesothermal gold vein deposit: Results o f a fluid inclusion, stable isotope, and thermodynamic study: British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1, p. 365-375. First author at Univ. British Columbia, Canada.

Results from FI and stable isotope studies, and thermodynamic modelling, have led to estimates of the P-T-X characteristics of mineralizing fluids in the Bralorne-Pioneer mesothermal Au vein deposits. Observed wall rock alteration mineral assemblages, and P-T conditions estimated from FI, were used to constrain a water-rock thermodynamic computer model. Stable isotope studies confirm that significant interaction of wall rocks with the ore fluid took place. The "fault valve" hypothesis of Sibson et al. (1988) offers an explanation for fluid migration, and is consistent with the main features of the ribbon-banded, yet coarsely crystalline quartz veins at Bralorne.

The major Au-bearing veins at Bralorne strike ~110° azimuth and dip north at 70°, with slickensides plunging 45° east indicating that the last movement was reverse. Major ore shoots occupy somewhat less than 20% of the veins and plunge steeply west, roughly perpendicular to the slickensides. The best host for veins seems to have been the competent Bralorne diorite (consisting of albite, hornblende and quartz) and the Cadwallader greenstone. The veins contain thin dark ribbons of fine-grained sulphide in massive milky quartz with minor calcite.

Hydrothermal alteration envelopes around the veins are extensive and grade outwards from intensely foliated quartz/ankeritic carbonate/sericite (+ fuchsite) to less sheared calcite/chlorite/albite to unsheared epidote/calcite. Chemical studies of the alteration on a constant volume basis (based on Al_2O_3 and TiO_2, which have remained relatively immobile), show that there has been addition of K_2O, CO_2, S, As and Au, while Na_2O, FeO (total) and MgO have been strongly depleted close to the vein. SiO_2 and CaO are locally depleted and reconcentrated.

Disseminated pyrite, pyrrhotite and much lesser chalcopyrite occur within envelopes for up to several meters from the veins. Arsenopyrite is confined to vein salvages. Minor amounts of sphalerite and especially galena appear to correlate with vein sections that are richer in Au. Traces of tetrahedrite and stibnite have been observed but tellurides have not. Au is principally found as thin smeared flakes of the native metal in the black sulphidic septae of the strongly ribboned shear veins. Au is only rarely found by itself in the quartz, usually in the rare extensional veins, where it forms extremely rich pockets. (Authors' abstract)

LEPIN, A.Yu., KONOVA, N.I. and **LISITSYN, A.P.**, 1989, New data on the nature of naphthoids from the hydrothermal system of the Guaimas Rift (California Bay): Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 207-211 (in Russian). First author at Inst. Geochem. and Anal. Chem., Moscow, USSR.

The paper presents gas chromatographic and isotope analyses of liquid naphthoids (C_{11}-C_{38}) collected from the seafloor sediments in October 1986. (A.K.)

LESPINASSE, M., 1989a, Tectonic structures and fluid inclusion trails (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 61. Author at CREGU et GS CNRS-CREGU, BP23, 54501, Vandoeuvre l0s Nancy Cedex, France.

Within the last few years, a number of studies have been undertaken on microcrack propagation mechanisms, and the spatial distribution of microcracks, in relation to local stress axes. Results indicate that most cracks appear to be extensional fractures (mode I cracks) propagated roughly parallel to the local maximum stress axis. However, geometric description of fracturing is not sufficient to establish a chronology between the different stages of the regional paleostress field. A new method of studying microcracks has been undertaken. The method relates microcrack propagation to stress tensors and the nature of the fracture infilling, paying special attention to the fluids trapped as FI along healed microcracks.

FI trails are oriented in a coherent manner relative to the regional structures. It has been shown that it is possible to discriminate between trails (i.e., between different generation of fluids) and to relate them to the regional history of the rock, using them as a structural marker of the bulk brittle deformation of the area. This approach has been tested in different granitic areas of the French Massif Central and shows that: (i) propagation of intragranular planes of FI are not dependent on intracrystalline orientations (C axis, subgrains boundaries); (ii) FI planes have similar orientations to other extensional cracks; they are mode I cracks formed parallel to the average direction of 1. FI planes could provide in the absence of mesostructural markers a useful tool in reconstructing the trajectories of extension direction; and (iii) according to their direction, several generations of fluids may be distinguished as a function of their physico-chemical characteristics (P, V, T, X). FI trails can thus be used to establish the chronology of faulting throughout a series of regional deformational events. (Author's abstract)

LESPINASSE, M., 1989b, Microfracturing and regional stress fields: Relation with fluid chronology and hydrothermal quartz leaching (episyenitization): Uranium deposits in magmatic and metamorphic rocks, Proc. Technical Committee Meeting on Uranium Deposits in Magmatic and Metamorphic Rocks, Salamanca, Sept. 29-Oct. 3, 1986: Int'l Atomic Energy Agency, Vienna, Austria, p. 57-76. Author at CREGU and GS CNRS-CREGU, Vandoeuvre-les-Nancy, France.

The study of the deformation of the La Marche granitic massif (northwest Central massif) indicates relations between palaeostress fields and the geometry of microfractures as defined by FI trails. The FI form rectilinear trails which correspond to healed microcracks. These contain percolating aqueous fluids associated with episyenitization and mineralization deposition. Simultaneous studies of the orientations in space of these trails and of the chemistry of these inclusions (microthermometric characteristics) indicate that: (a) FI trails are extensional cracks which can be used as excellent markers of palaeostress fields; (b) several generations of fluids can be distinguished according to their physico-chemical characteristics (composition and T), corresponding to different stages of hydrothermal activity. The Le Bernardan U ore deposit shows that the relations between regional stress fields, the geometry of the FI trails and the microthermometric characteristics of the fluids may be used to establish the chronology of both faulting and fluid circulation during a region's geological evolution and to predict the proximity of ore bodies. (Author's abstract)

LEUNG, I.S., 1989, Multi-colored silicon carbide occurs in two diamond mines in China (abst.): Eos, v. 70, p. 511.

LEWAN, M.D. and **BUCHARDT, B.**, 1989, Irradiation of organic matter by uranium decay in the Alum Shale, Sweden: Geochim. Cosmochim. Acta, v. 53, p. 1307-1322. First author at Amoco Prod. Co., Res. Center, P.O. Box 3385, Tulsa, OK 74102, USA.

The Alum Shale of Sweden contains black shales with anomalously high U concentrations in excess of 100 ppm. Syngenetic or early diagenetic origin of this U indicates that organic matter within these shales has been irradiated by decaying U of approximately 500 Ma. Radiation-induced polymerization of alkanes through a free-radical cross-linking mechanism appears to be responsible for major alterations within the irradiated organic matter. Specific radiation-induced alterations include generation of condensate-like oils at reduced yields from hydrous pyrolysis experiments, decrease in atomic H/C ratios of kerogens, decrease in bitumen/organic-C ratios, and a relative increase in low-molecular weight triaromatic steroid hydrocarbons. Conversely, stable C isotopes of kerogens, reflectance of vitrinite-like macerals, oil-generation kinetics, and isomerization of 20R to 20S $\alpha\alpha$ C_{29}-steranes were not affected by radiation.

The radiation dosage needed to cause the alterations observed in the Alum Shale has been estimated to be in excess of 10^5 Mrads with respect to organic C. This value is used to estimate the potential for radiation damage to thermally immature organic matter in black shales through the geological rock record. High potential for radiation damage is not likely in Cenozoic and Mesozoic black shales but becomes more likely in lower Paleozoic and Precambrian black shales. (Authors' abstract)

LEWIS, R.D. and **SHIEH, Y.N.,** 1989, ^{18}O, ^{34}S and geochemical investigation of the Au-Ag hydrothermal system associated with the Republic Mining District, Ferry County, Washington (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A296. First author at Waterways Experiment Station, Vicksburg, MS 39180.

The Au-Ag Republic Mining District has been in almost continuous production since the late 1800's. The epithermal system from which the mineralization resulted has been narrowly dated from unconformable relationships and K-Ar age determinations to be between 51 to 46 m.y. old. The hydrothermal system based upon alteration investigations was mainly confined to the central western flank of the Republic graben, northeastern Washington. The T of the main stage Ag-Au mineralization fluid based upon O isotope fractionation of quartz-calcite pairs averaged near 360°C. Fluid inclusion Th were generally 20°C cooler than the isotopic T. The fluid inclusions also demonstrated that the system was water- rather than vapor-dominated and exhibited a salinity of 0.3 wt % NaCl. Late stage mineralization displayed isotopic T from 340°C to 190°C. The T of the hydrothermal system decreases with paragenetic sequence from +400 to 190°C. At the same time, the ^{18}O of the hydrothermal fluid decreases from -0.5 to -8.5‰. This indicated that the hydrothermal fluid was ultimately meteoric in origin and exchanged lesser amounts of ^{18}O with the rhyodacite wallrock with time and decreasing T. The unaltered rhyodacite wallrock contained whole rock ^{18}O values 9.1 to 5.5‰. Hydrothermally altered samples (chiefly intermediate argillic) produced whole rock ^{18}O down to -3.1‰ with a -0.5 average. The wall rock was noticeably petrologically *and* isotopically altered for several hundred meters from the main mineralized veins. An average ^{34}S isotopic value for the main stage pyrite was -1.2‰ which indicates the sulfur was igneous in origin and the system H_2S dominated. The potential for using stable O isotopes for further exploration in this district is great. (Authors' abstract)

LI, Binglun, XIE, Yihan, LI, Ruomei and **WANG, Yinglan,** 1989, Basic characteristics of Mesozoic porphyry-type deposits in Eastern China: Mineral Deposits, K'uang Ch'uang Ti Chih, v. 8, (3), p. 3-13 (in Chinese).

Indexed under FI. (E.R.)

LI, Ning, FENG, Zhongyian and **YU, Fang,** 1989, Genesis of the Beiluoxia skarn iron deposit in Shanxi Province: Fluid inclusion evidence: Mineral Deposits, v. 8, no. 3, p. 43-54 (in Chinese, English abstract). Authors at Dept. Geology, Peking Univ., Beijing, P.R.C.

The Beiluoxia skarn Fe deposit in Shanxi Province is a replacement product of Middle Ordovician limestone adjacent to a Mesozoic diorite phacolith. The diorite intrusion has been strongly albitized towards the ore bodies. Post-magmatic hydrothermal and albitization fluids served as the main Fe source for the Beiluoxia deposit. The major gangue minerals include early diopside and garnet and late epidote and calcite. Magnetite precipitated earlier than epidote but later than garnet. The fluid inclusions can be divided into three compositionally distinct groups: (A) liquid + gas + multiphase solids (540-660°C, with salinities of 50-70 NaCl wt % eq.); (B) liquid + gas (+ halite) (240-525°C, 1.6-42 NaCl wt % eq.); (C) gas + liquid with gas phase > 50 (240-460°C). Type A mostly appears in diopside, whereas Type B and C mainly occur in calcite, garnet and epidote. All of these types of inclusions are traces of metallogenic fluids throughout the principal ore-forming process.

The fluid inclusion evidence shows that the fluids belong to the Na-Ca-Cl-SO_4 system with abundant Fe in the early stage. Type A fluid, having the highest Th and containing great amounts of Fe, Na and Cl, is considered to be the main ore-forming fluid. This is further supported by the fact that, of all inclusions, only Type A ones contain small crystals of hematite. Magnetite precipitation resulted from rapid decrease in fluid T. Fluid inclusions in calcite coeval with magnetite show indications of fluid boiling. (Authors' abstract)

LI, Rongqing, 1988, Mineralogy of calcite from the Fankou lead-zinc deposit of northern Guangdong and its relationship with mineralization: Acta Petrol. Mineral., v. 7, no. 4, p. 347-355 (in Chinese, English abstract). Author at Hunan Institute of Geology.

Calcites are dominant gangue minerals in the Fankou Pb-Zn deposit and were formed at three stages. The studies in such aspects as chemical composition, cell parameters, physical characters, carbon-oxygen isotopes, fluid inclusions and thermoluminescence demonstrate that the calcite formed during the Fe-Pb-Zn sulfide stage is different from that formed in pre- or post-mineralization periods in that the former contains more Mn and has shorter axes and slightly higher specific gravity, hardness, and refractive indices. In addition, $\delta^{13}C_{PDB}$ (‰) of the former calcite varies from -5.25 to -8.15, Th range from 163°C to 219°C, and ATL/NTL ratios are distinctly greater. It is obvious from these results that the mineralization in the Fankou Pb-Zn deposit is related to the hydrothermal process. (Author's abstract)

LI, Zhaolin, 1989, Intergranular solution and mineralization (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-297. Author at Sun Yatsen Univ., Guangzhou, P.R.C.

Based on geological field observations of more than 20 hydrothermal ore deposits, in conjunction with fluid inclusion studies, high-temperature and high-pressure experiments, and elemental geochemistry data, this paper discusses the melt solution nature of granitic magma and the mechanism of formation of intergranular solutions during cooling and local differentiation of the granitic magma.

Evidence from fluid inclusion studies—The coexistence of melt inclusions and gas-liquid inclusions is observed in quartz from deep-source granites, such as the Suzhou granite and Kuiqu granite. The homogenization T range from 1140 to 980°C for melt inclusions and from 580 to 180°C for gas-liquid inclusions.

Statistical analysis of the inclusion data obtained from 30 granite bodies and associated ore deposits in South China shows that inclusions in quartz from both quartz veins and their host granites are quite similar in homogenization temperature.

No significant difference is noticed between unaltered and areally altered granites in homogenization temperature for inclusions in quartz. The chemical compositions of fluid inclusions in quartz from granites and ore-bearing quartz veins are similar. Similar isotopic compositions of fluid inclusion in the two types of quartz have been reported. (From authors' abstract by E.R.)

Table 1. Homogenization temperature (0°) [sic; °C] of inclusions in granite-hosted quartz and vein quartz.

	Granite		Metasomatite	Quartz vein
Locality	Melt inclusion	Gas-liquid inclusion	Gas-liquid inclusion	Gas-liquid inclusion
Xihuachan W deposit		420-180	280-190	309-120
Dajishan W deposit	1150-1000	400-190	320-220	340-260
Sanshandao Au deposit	940-700	460-300		460-300
Yangchuling porphyry W deposit	1250-1100	400-200	265-160	360-170
Gejiu Sn deposit	1140-850	500-200		425-290

LIANG, Shuyi and XIA, Hongyuan, 1989, Silver and sulfosalt minerals in tungsten deposits, South China: Chinese J. Geochem., v. 8, no. 2, p. 135-145 (in English). Authors at Chengdu Geol. College, Chengdu, P.R.C.

Ag occurs in South China wolframite-quartz veins in three forms: (1) as micro inclusions of Ag_2S and $AgBiS_2$, (2) as argentite and matildite as a result of exsolution from galena, and (3) as Ag-bearing sulfosalts and independent Ag minerals.

According to mineral assemblages the Ag-bearing W deposits are classified as two types: (1) Ag-bearing W-Bi deposits in eastern Nanling, where gustavite has been found, and (2) Ag-bearing W-Sn(Sb) deposits which are mainly distributed in western Nanling. The authors consider that the enrichment of Ag and sulfosalt minerals in the lower parts of pneumato-hypothermal W deposits is the result of reversed vertical zoning caused by high concentrations of F and S in the ore-forming fluids. (Authors' abstract)

Th (quartz) ranges from 167-295°C; Td (wolframite 309-370°C). (E.R.)

LIGHT, T.D., BREW, D.A. and ASHLEY, R.P., 1989, The Alaska-Juneau and Treadwell lode gold systems, southeastern Alaska: U.S. Geol. Surv. Bull. 1857, p. D27-D36. First author at U.S. Geol. Surv., Anchorage, AK.

Use literature data only. (H.E.B.)

LIN, Zhuoran and FAN, Qicheng, 1986, Some microstructures observed in a mantle derived olivine by HVEM: Proc. XIth Int. Cong. on Electron Microscopy, Kyoto, p. 1129-1130.

LIN, Zhuoran, LIU, Ruoxin, FAN, Qicheng and VOGT, Henning, 1989, Enrichment of trace elements in fluid inclusions of mantle-derived olivine: Evidence newly provided by LAMMA analysis, *in* Proc. 12th Int'l Conf. on X-ray Optics and Microanalysis: Cracow, Poland (4 pp., unnumbered). First author at Inst. Geology, SSB P.O. Box 634, Beijing 100011, P.R.C.

The newly developed LAser Microprobe Mass Analysis (LAMMA) technique has been employed to make a simultaneous comparative analysis between the fluid inclusions and the matrix on a mantle-derived olivine. Preliminary result has shown evident enrichment of Li, C, Sc, Ti, V, Co, Ge, As, Zr, Nb, Ru, Cd, Sn, Cs, Cu, Sr, In, LREEs and HREEs in the fluid inclusions over the olivine matrix, providing new evidence of partial melting and new geochemical data for the study of metasomatism and evolution of the earth mantle. (Authors' abstract)

LINDBLOM, S., 1989, Raman spectroscopy and microthermometry on Swedish gold ores (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 62. Author at Ore Res. Group, Dept. Geol., Univ. Stockholm, S106 91 Stockholm, Sweden.

Au has mainly been mined in Sweden as a by-product from the two principal massive Fe-Cu-Zn (Pb-Ag) sulphide-bearing regions, the Bergslagen and the Skellefte ore field provinces. Actually, only two deposits have been mined solely for their Au content: the Adelfors deposit (little affected by metamorphism) as quartz veins in supracrustal rocks and the Enasen deposit (highly metamorphosed, up to granulite facies) in sheared, quartzitic host rocks consisting mainly of quartz and sillimanite with traces of biotite and cordierite.

For Adelfors, aqueous FI indicate formation of the quartz in several stages between 100 and 300°C from a solution of initially 7 wt % NaCl eq. Later metamorphic solutions of lower salinities and slightly higher T are also indicated. Boiling appears to have occurred during some stages. At Enasen, FI are dominated by CO_2 with minor N_2. Both microthermometry and Raman analysis indicate up to 5 mole % N_2. A possible separate N_2 generation of inclusions is indicated by gas analysis of FI by mass spectrometry.

The FI results are further discussed [and compared] with Cenozoic deposits in Nevada (From author's abstract by E.R.)

LINDBLOM, Sten and BURKE, Ernst, 1988, Raman spectrometry and microthermometry data on CO_2-CH_4-bearing fluid inclusions in late-orogenic quartz from the Saxberget Zn-Pb-Cu-Ag deposit, Central Sweden: Geol. Mijnbouw, v. 67, p. 471-476. First author at Geol. Inst., Stockholms Univ., Kingstengatan 45, 106 91 Stockholm, Sweden.

Aqueous inclusions gave Tm ice of -3 to -5°C and Th of 138-201°C. Most contain much CO_2 with $ThCO_2(L)$ +16.9 to +24.3 and $TmCO_2$ -58.0 to -57.4°C. Raman studies showed no N_2, O_2, SO_2, H_2S, CO, H_2, NH_3 and C_2H_6; only CO_2 and CH_4 (~90 mole to CO_2, and 3-7% CH_4). The calculated isochore agrees with P-T field of local metamorphism from late-orogenic granites (500°C and 250 MPa). (E.R.)

LINDBLOM, S. and DORYPHOROS, C., 1989, Fluid inclusion studies on sandstone environments related to lead-zinc ore deposition (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-302-303. Authors at Stockholm Univ., Stockholm, Sweden.

Fluid inclusions in interstitial sphalerite and calcite in sandstone-hosted Pb-Zn deposits along the 1500 km long marginal zone of the Scandinavian Caledonides show Th varying between 100°C and 250°C with the majority of sphalerite T between 130°C and 180°C. Detailed measurements reveal several stages of deposition, each with distinct modal T. The largest deposit, Laisvall, indicates mixing of two solutions with calcite initially precipitating from a heated groundwater solution of lower salinity followed by sulfide deposition during mixing with an incoming hot brine and simultaneous dissolution of calcite. The same scenario is indicated from the other deposits along the length of the Caledonides. The host rock is generally an autochthonous sandstone, well sealed and almost quartzitic, but else very little disturbed in most places. In some deposits Pb-Zn mineralization does occur in translated nappe units of local movement. This has not affected fluid inclusion data. Tm ice vary between -9°C and -38°C, in detail indicating several stages of the mixing process and also showing that appreciable amounts of other salts besides sodium chloride are present in the inclusions. Chemical analysis of the fluid inclusions in detrital quartz has given K/Na and Ca/Na ratios of 0.1 and 0.23, respectively, which correspond to published values from carbonate-hosted Mississippi Valley type deposits. This indicates that fluid inclusion data from detrital quartz in sandstone-hosted deposits may provide information about the ore-forming environment. This is particularly the case in Laisvall where we have a very clean well-sealed sandstone but with little diagenetic overgrowth and pressure solution textures. Sandgrains are very clear with solid inclusions mainly besides the aqueous inclusions that give data of Th between 90 and 230°C and Tm ice between 0°C and -30°C. Inclusions in detrital grains are comparatively few because the grains are well rounded, and earlier formed S inclusions have disappeared as planes of weakness have been broken up during transport. The Tm distribution is bimodal with one population mode around -1.5°C and one around -15°C. This distribution is similar to the one for calcite at Laisvall and points more toward the general mixing model suggested than to earlier generations of inclusions.

Differences between sandstone environments will be discussed as reflected in variations in fluid inclusion data. In general, the following tentative conclusions are forwarded:

1. Sandstone-hosted deposits may provide a more exact chemical database for MVT ores than carbonate-hosted deposits because of the relatively inert character of the host rock.

2. A model of deposition involving mixing of two solutions is indicated by fluid inclusion data in the context of physical parameters and spatial distribution.

3. Fluid inclusion data from the entire 1500 km along Caledonian front in Scandinavia indicate similar deposition conditions.

4. Detrital quartz fluid inclusions may provide a guide to the ore-forming environment in sandstone-hosted Pb-Zn deposits. (Authors' abstract)

LINDBLOM, Sten, RANKIN, A.H. and **THOMPSON, Michael,** 1989, Fluid inclusion composition of Baltic Shield quartz associated with mineralization, Sweden: Applied Geochem., v. 4, p. 473-481. First author at Ore Research Group, Dept. Geology, Univ. Stockholm, S-106 91 Stockholm, Sweden.

Fluid inclusions in quartz from seven ore districts in Sweden have been analyzed by the decrepitation-ICP method. The geological setting of the deposits varies from a sedimentary sandstone environment to highly metamorphosed rocks in the amphibolite facies.

Major components Na, K and Ca give variable but interpretable information about fluids involved in ore deposition and subsequent metamorphism. The K/Na and Ca/Na ratios are very consistent even at low salt concentrations in the fluids and may be used to distinguish the origin of the involved mineralizing brine solutions. Feldspar contamination does not affect the ratios.

Decrepitation-ICP data in the present study are consistent with the microthermometry and geochemistry of the deposits. The base metals Cu, Fe and Zn give significant results agreeing with the mineralogy of the deposit. (Authors' abstract)

LINDSLEY, D.H. and **NEKVASIL, Hanna,** 1989, Termination of the two-feldspar + liquid curve in the system Ab-An-Or(-H_2O): Revisited yet again! (abst.): Eos, v. 70, p. 1395.

LINNEN, R.L. and **WILLIAMS-JONES, A.E.**, 1989, Pegmatite-hosted Sn-W mineralization at Nong Sua, Thailand (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-69. Authors at Geol. Sci., McGill Univ., 3450 University St., Montreal, Quebec H3A 2A7, Canada.

Tin-tungsten mineralization at Nong Sua is hosted by a sill-like intrusion comprising laterally continuous layers of pegmatite and aplite which was emplaced in psammitic metasediments approximately 180 km south of Bangkok. Several pegmatite and aplite types can be distinguished on the basis of mineralogy, i.e., on the presence or absence of tourmaline and/or muscovite and/or garnet. Quartz, plagioclase, and K-feldspar (perthite) are present in all these lithotypes. Myrmekitic and graphic intergrowths of quartz and feldspar and skeletal tourmaline are common in pegmatite, indicating that there was water saturation during crystallization. Cassiterite is present either as disseminations in tourmaline pegmatite, typically intergrown with tourmaline, or in quartz-wolframite veins in two of the aplite units. The veins cut the layering of these aplite units at high angles but do not extend outside their boundaries. Five types of FI have been observed: (1) aqueous liquid-rich (LV), commonly containing carbonic vapor—the dominant inclusion type in cassiterite and tourmaline, and less common in quartz; (2) aqueous-carbonic liquid-rich (LLV)—abundant in quartz, but less common in cassiterite and tourmaline; (3) aqueous-carbonic vapor-rich (VL)—observed in cassiterite, tourmaline, and quartz; (4) aqueous liquid-rich containing halite ± other birefringent solids (LVHS)—observed only in quartz; (5) aqueous liquid-rich, containing up to eight birefringent solids (LVS), observed in cassiterite, tourmaline, and quartz. Microthermometric studies have been initiated on type 1 inclusions and show that they range in composition from 2 to 20 wt % NaCl eq. and homogenize between 200° and 400°C. Pseudosecondary type 1 inclusions in cassiterite have high salinity and homogenize at high T indicating that they are probably of magmatic origin and that the cassiterite therefore probably precipitated from magmatic fluids. (Authors' abstract)

LIRA, R. and **RIPLEY, E.M.**, 1989a, Fluid inclusion studies of the Rodeo de Los Molles REE and Th deposit, Las Chacras batholith, central Argentina (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 42. First author at Dept. Geol., Nat'l. Univ. Cordoba, CONICET, Velez Sarsfield 299, (5000) Cordoba, Argentina.

The Rodeo de Los Molles rare earth and Th deposit is located in granitic rocks of the Las Chacras-Piedras Coloradas batholith, in the southern block of the Eastern Pampean Ranges, central Argentina. Mineralization occurs within an elongated (2 km x 0.6 km) body of alkali feldspar granite (alaskite) localized along the northeastern edge of the batholith, and surrounded by the predominant biotite monzogranite facies. Petrographic and chemical analyses suggest that the alaskite was produced by hydrothermal alteration of the monzogranite. REE minerals are primarily from the Ce group, and include britholite $(Na, Ce, Ca)_5[F(SiO_4, PO_4)_3]$ and allanite, both partially replaced by bastnasite $(Ce(CO_3)F)$ or thorbastnasite $((Ce, Th)(CO_3)F)$. These minerals occur as nodules with quartz (Q1), fluorite (F1), hedenbergite, sphene, and Fe-Ti oxides within aplitic-pegmatitic areas of the alaskite. Uranoan-thorite occurs in the alaskite with quartz (Q2) and fluorite (F2) in nodules, veins, or linings of miarolitic cavities, but is not found with the Ce-mineralization.

FI in Q1 are two-phase (L + V) with low salinities of 1 to 3 eq. wt % NaCl, and P corrected Th of 595 to 642°C. S inclusions have moderate salinities of 8 to 25 eq. wt % NaCl, and Tt of 350 to 445°C. F1 is paragenetically later than Q1, and associated with carbonate alteration of the primary REE minerals. PS inclusions in F1 are low salinity, mixed H_2O-CO_2. Th CO_2 and Tm clathrate range from 28.2 to 29.1°C and 7.5 to 7.8°C, respectively. A CO_2 density of 0.75 g/cc is estimated, with a fluid salinity of ~5 eq. wt % NaCl. Minimum P and T estimates based on CO_2-H_2O-NaCl phase relations are 1.8-2.3 kbar and 489 to 545°C. Computed $X(CO_2)$ values are ~0.14, in agreement with CO_2/H_2O ratios determined by mass spectrometric analyses of inclusion fluids collected by decrepitation. P inclusions in Q2 exhibit Tt ~50°C lower than Q1, and are similar in salinity (3 eq. wt % NaCl). T of 463-502°C are recorded for P inclusions in F2, with salinities of 35 wt % based on halite melting. S inclusions in both Q2 and F2 are characterized by similar T (260-380°C) and salinities (5-20 eq. wt % NaCl). Mass spectrometric analyses of inclusion fluids indicate $X(CO_2)$ values <.06 δD values of water extracted from FI at various T steps range from -91 to -123‰. $\delta^{18}O$ values of pegmatitic quartz varies from 11.1 to 14.2‰, and is heavier than quartz in the adjoining granitic rocks. Computed $\delta^{18}O(H_2O)$ values range from 8 to 10‰.

The data suggest a complex history of open system fluid migration and interaction with granitic rocks near the margin of the batholith. Both Ce- and Th-mineralization are associated with mixed CO_2-H_2O-NaCl fluids, but formed at different times in the late magmatic-hydrothermal evolution of the system. Isotopic data are consistent with mineralization from magmatic H_2O, with low δD values caused by Rayleigh fractionation of a magmatic vapor phase. (Authors' abstract)

LIRA, R. and **RIPLEY, E.M.**, 1989b, Mineralogic and stable isotopic studies of Rodeo de Los Molles REE and Th deposit, Las Chacras Batholith, Central Argentina (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-306-307. First author at Nat'l Univ. Cordoba, CONICET, Cordoba, Argentina.

The Rodeo de Los Molles rare earth and thorium deposit is located in granitic rocks of the Las Chacras-Piedras Coloradas Batholith, in the southern block of the Eastern Pampean Ranges, Central Argentina.

Preliminary T estimates for the monzogranite using magnetite-ilmenite pairs suggest crystallization T between 600 and 650°C. In the alkali feldspar granite the coexistence of Or94-96 and pure albite suggests that final equilibration occurred below 350°C, in the presence of an aqueous phase. Th of fluid inclusions from quartz and fluorite associated with REE mineralization range from 200 to 400°C and are consistent with the estimated feldspar equilibration T.

$\delta^{18}O$ values of quartz from both the monzogranite and alkali feldspar granite range from 8.6 to 10.7‰. Quartz from pegmatite-aplite zones is isotopically heavier, with values ranging from 11.1 to 14.2‰. Quartz-feldspar Δ values range from -1.2 to +2.1 in both granitic facies, with most values within 0 ± 0.5. In conjunction with mineralogical evidence, the non-equilibrium Δ values suggest that feldspar continued to exchange isotopes to much lower T than quartz in the presence of a pervasive fluid phase. The data are consistent with low-T alteration by a magmatic hydrothermal fluid with a $\delta^{18}O$ values near 7-8‰, and W/R (atomic) values ≤ 1. High $\delta^{18}O$ values of quartz from pegmatite-aplite zones are consistent with relatively low-T crystallization from a residual, water-rich fluid.

δD values of biotite range from -78 to -114‰, with most values falling between -80 and -90‰. The lower δD values occur within ore zones or at the margins of the pluton. δD values suggest that exsolution of large amounts of a magmatic vapor phase has occurred, and biotite initially crystallized from a deuterium-depleted melt.

Geologic and geochemical data support the premise that ore-bearing zones at Rodeo de Los Molles resulted from a complex interaction between late-stage, magmatic aqueous fluids and previously crystallized monzogranite. Relatively incompatible elements were concentrated in the residual fluids and localized within apatite-pegmatite zones. Ore deposition and hydrothermal alteration apparently continued to T below 300°C. (From authors' abstract by E.R.)

LISITSYN, A.P., BOGDANOV, Yu.A., ZONENSHAYN, L.P., KUZ'MIN, M.I. and **SAGALEVICH, A.M.**, 1989, Hydrothermal phenomena in the Mid-Atlantic Ridge at Lat.26°N (Tag Hydrothermal Field): Izvestiya AN SSSR, seriya geologicheskaya, 1989, no. 12, p. 3-20 (in Russian; translated in Int'l Geol. Rev., v. 31, p. 1183-1198). Authors at Inst. Oceanology, USSR Academy of Sciences, Moscow, U.S.S.R.

LIU, Jianming, 1989, Genesis of the Zhilintou gold-silver ore deposit and hydrothermal gold-silver ores in the volcanic zones of S.E. China: Heidelberger Geowiss. Abh., v. 26, no. 223, 181 pp. (in German, English abstract).

The Zhilintou Au-Ag ore deposit is located in the southeastern coastal area of China. In the ore field, Upper Mesozoic acidic volcanic rocks and underlying Precambrian metamorphic rocks are exposed. The metamorphic host rocks of Au-Ag rich quartz veins consist mainly of a variety of gneissic rocks with well-developed fissure systems. Hydrothermal alterations, such as silification, sericitization, chloritization, etc. are often observed along the fissures. This Au-Ag deposit consists of quartz veins (up to 26 m thick) developed along a tension-shear fissure zone. The ore veins are characterized by open-space filling by hydrothermal solutions with typical banded and zoned textures, and hydrothermal explosive breccias, as well as colloform deposition, comb structures and drusy cavities. In the quartz veins, Au and Ag are irregularly distributed with ore shoots commonly found in the central part of the veins.

According to fluid inclusion studies, this ore deposit was formed at 180°C to 350°C and a depth <1.9 km. During the ore-forming process, the decrease of P was remarkable, which resulted in repeated boiling or exploding of the ore fluid. The ore-forming solution was relatively acid and poor in sulfur. Both Cl^--activity and salinity of the solution were medium. Au and Ag were mobilized in [chloride] solutions and precipitated mainly in response to the P decrease and boiling.

Generally, the epithermal Au-Ag ore deposits are formed in geothermal systems which are related to magmatic processes. They correspond to the metal-rich precipitates of modern geothermal systems in the continental crust. The possible ore-forming and related ore zonation in such geothermal systems is, from the earth surface to the batholith: hot spring type (Au, Hg) → epithermal type (Au, Ag) → epithermal type (Pb, Zn, Ag) → porphyry type (Cu, Mo) → skarn type (Cu,Sn) → quartz vein or greisen type (W, Sn). (From authors' abstract by E.R.)

LIU, Jiaqi and **CHANG, Hailing,** 1989, A study on the origin of the Damingshan tungsten deposit, Guangxi: Bull. Yichang Inst. Geology and Mineral Resources, Chinese Acad. of Geological Sciences, no. 14, p. 171-180. Authors at Yichang Inst. Geology and Mineral Resources, CAGS, P.R.C.

The Damingshan W deposit is located in the plunging end of the Damingshan anticline. There are three types of W ores: (1) stockwork orebodies in porphyritic muscovite granite; (2) stratiform orebodies formed by filling of quartz veinlets into intrastratal fissures in sandy shale; and (3) large quartz vein-type orebodies filling fissures in porphyritic muscovite granite or its country rocks. They all have a close genetic relationship with late Yanshanian porphyritic muscovite granite.

The paper deals with the research work on the following aspects: the characteristics of porphyritic muscovite granite and three types of W ores, ore textures and structures, mineral association, chemical composition of wolframite, T and composition of melt inclusions in porphyritic muscovite granite, the character, T, salinity and chemical composition of FI in the three types of W ores, and H, O and S stable isotopic composition. Based on the research work several conclusions can be drawn:

In the quartz of phenocrysts of granite, the crystalline phase of melt inclusions is mainly muscovite, making up over 50%; the glassy phase accounts for ~30-35%, and the gaseous phase 15%; and the Tf ranges between 870 and 920°C. The melt inclusions of quartz in the matrix are mainly glassy and the Tf ranges from 780 to 870°C.

Inclusions in the W deposit are mainly fluid (the liquid phase accounts for ~70 to 80%) with unsaturated NaCl (no dms). Tf of the FI ranges from 310 to 360°C (corrected for P). The salinity ranges from 7 to 8 eq. wt % NaCl. The components of the gaseous phase in the FI are mainly H_2O with trace amounts of CO_2, CO, N_2, CH_4 and H_2. The liquid phase in the FI is rich in K^+, Na^+ and Cl^-; F^- with $K^+ > Na^+$ and $Cl^- > F^-$, while the Ca^{2+} and Mg^{2+} contents are very low.

The characters of the H, O and S stable isotopic compositions are similar in the three kinds of W ores: the $\delta^{18}O$ value of quartz is +12 to +13‰; the $\delta^{18}O(H_2O)$ value of ore-forming fluids is +6 to +7‰; the $\delta D(H_2O)$ value of the FI in quartz is -48.9 to -51.8‰; the $\delta^{34}S$ values of molybdenite and chalcopyrite are -0.1 to +0.3‰, which suggests that the ore-forming fluids should originate from postmagmatic hydrothermal solutions. Thus the direction in W prospecting has been pointed out, i.e., the areas surrounding the late Yanshanian small porphyritic muscovite granite intrusions are favourable for W prospecting. (From authors' abstract by E.R.)

LIU, Xiaoshan and **SUN, Xiaoming,** 1989, Fluid inclusion and stable isotope studies of the Jinduicheng Mo-deposit: Geology and Prospecting, v. 25, no. 2, p. 12-19 (in Chinese, English abstract).

Through studies of fluid inclusions and stable isotope compositions of the Jinduicheng Mo-deposit, it is noted that the ore-forming T and P of the deposit are <300°C and ~100 bars, respectively. The mineralizing hydrothermal solution has a salinity <20%, showing a tendency to decrease from the early to late stage. The solution of the early stage, mainly of juvenile water, is rich in K^+, while that of the middle and late stages, into which much more meteoric waters were introduced, is rich in Ca^{2+} and HCO_3^-. Experimental results indicate that the solution has a large value of fS_2, and the ore-forming element is migrated in the form of complexes Na_2MoS_4 and K_2MoS_4 (in the early stage) and H_2MoS_4 (in the late stage). In addition, migration of Mo^{6+} in the form of complex CO_3^{2-} or HCO_3^- is also possible due to a higher content of HCO_3^- in the solution. (Authors' abstract)

LIU, Yinchun, 1989, Geochemical signatures of the Hungjindong gold deposit: Geology and Prospecting, v. 25, (11), p. 43-48 (in Chinese).

Indexed under FI. (E.R.)

LOBO, V.M.M., 1989, Handbook of Electrolyte Solutions: Part A and **LOBO, V.M.M.** and **QUARESMA, J.L.,** Handbook of Electrolyte Solutions: Part B: Physical Sciences Data 41, Elsevier, 2354 pp.

LONDON, David, 1989, Lithophile rare element concentration in peraluminous silicic systems: Summary of experimental results with Macusani glass (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-32.

LORAND, L.P. and **CEULENEER, G.**, 1989, Silicate and base-metal sulfide inclusions in chromites from the Maqsad area (Oman ophiolite, Gulf of Oman): A model for entrapment: Lithos, v. 22, p. 173-190. First author at Laboratoire de Minéralogie du Muséum National d'Histoire Naturelle, CNRS URA 286, 61 rue de Buffon F-75005 Paris, France.

Al-rich chromites from the Maqsad area (Oman ophiolite) have been studied to propose a genetic model for silicate and base-metal sulfide (BMS) I entrapment. Samples were collected in both concordant and discordant nodular pods and in a peculiar stratiform ore; chromite ore contains olivine + clinopyroxene + plagioclase as interstitial silicates. Regardless of the ore type, the silicate I are, in decreasing order of abundance, composed of Ti- and Na-rich phlogopite, Ti-pargasite, enstatite, Mg-diopside, olivine, albite and secondary hydrothermal products. Chromite-hosted BMS are dominated by pentlandite, heazlewoodite, millerite and are nearly devoid of Fe- and Cu-sulfides.

The samples which come from concordant ores are very poor in mineral I, a consequence of the strain-induced grain boundary migration and recrystallization which they suffered during plastic deformation. In contrast, the nodular and stratiform samples which escaped post-magmatic deformation and densification are I rich. The I display negative crystal shape following the chromite symmetry. If present in nodular samples, they may be arranged as coronas which mimic the shape of the host chromite grains. All these textural features are considered to be evidence for mineral I entrapment during magmatic precipitation of chromite. By reference to a previous dynamic model of chromite ore genesis, we consider that the nodules of chromite crystallized from basaltic magma were flowing inside a narrow cavity in which a non-turbulent convective system was established. We deduce from the presence of several I coronas or patches in the largest nodules and their absence in the smallest, that the I were trapped preferentially at the point in which the primitive magma flow meets the convective current.

The peculiar mineralogy of mineral I dominated by hydroxyl-sodic phases indicates a complex interaction at the magmatic stage between the chromite-precipitating magma and an unrelated aqueous fluid phase. This fluid, which was Na- and S-bearing, travelled through the top of the mantle sequence and the basis [base?] of cumulate rocks of the ophiolite. It could have been injected at certain stages of its evolution in the same conduits as the chromite-precipitating magma, locally giving rise to volatile-enriched differentiated melts. The latter have been sealed together with the liquidus phases of magma (olivine, clinopyroxene, orthopyroxene and plagioclase) as I during chromite growth and/or dissolution. Olivine and pyroxenes have partly reacted with the trapped volatile-rich melt, producing phlogopite and pargasite several hundred degrees below Tt. BMS have formed through sulfidization reactions with enclosed silicates and/or host chromite. (Authors' abstract)

LORTIE, R.B. and **CLARK, A.H.**, 1987, Strata-bound cupriferous mineralization associated with continental rhyolitic volcanic rocks, Northern Chile: I. The Jardin copper-silver deposit: Econ. Geol., v. 82, p. 546-570.

A few two-phase I gave Th of ~140 ± 20°C, with maximum values up to 250°C. (E.R.,

LOSH, Steven, 1989, Fluid-rock interaction in an evolving ductile shear zone and across the brittle-ductile transition, Central Pyrenees, France: Am. J. Sci., v. 289, p. 600-648. Author at Dept. Geological Sciences, Snee Hall, Cornell Univ., Ithaca, NY 14853.

Alpine (early- to mid-Tertiary) overthrusting involving Pyrenean Axial Zone basement rocks was accompanied by displacement on high-angle retrograde ductile shear zones exposed in the granodiorite of the Neouvielle Massif, France. Shear zone products, generally formed from a quartz-bearing granodiorite precursor, were syntectonically exhumed across the brittle-ductile transition for quartz, marked by a silicified brecciated zone. Mass balance for retrograde sericitization and chloritization reactions in the ductile products below the B-D transition indicates a net loss of silica from the ductile shear zone products. A fluid/rock ratio on the order of 4 x 10^4 kg fluid per cubic meter of shear zone production is calculated based on silica production and solubility. O-isotope data indicate that the ductile products exchanged with large volumes of throughgoing fluid (initial $\delta^{18}O$ probably = 10-15‰). Tectonic reconstruction indicates that this fluid was most likely derived from syntectonic devolatilization reactions occurring in overthrusted footwall metasediments. By contrast, a band of brittly deformed feldspathic cataclasite structurally below the quartz B-D transition in one shear zone tapped descending, chemically distinct formation waters ($\delta^{18}O$ = 2-7‰) derived from overlying carbonates. The two fluids locally mixed in the ductile shear zone, as indicated by shifts in $\delta^{18}O$ of some ductile products to lighter values. Fluids from the two reservoirs probably passed the B-D transition by means of earthquakes, which seismically pumped batches of formation water downward and created fractures in the silicified breccia zone, allowing escape of ascending metamorphic fluids. (From author's abstract)

Th on 23 I or groups of I are presented (p. 613), ranging from 155-300°C; these yield Tf of 270-450°C. (E.R.)

LOUCKS, R.R., 1989, Hysteresis of fluid inclusion homogenization temperature by liquid-vapor surface tension (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 43. Author at Dept. Earth and Atmosph. Sci., Purdue Univ., West Lafayette, IN 47907.

A previously unquantified source of error in routine FI geothermobarometry is examined quantitatively and found to be of major significance for aqueous inclusions formed in sedimentary diagenetic and similarly low-T (<200°C) environments. FI can *never* undergo liquid-vapor homogenization at exactly the T at which the inclusion cavity became sealed off from its external environment. In principle, estimates of FI density and Tt that are based on measurements of the T of liquid-vapor homogenization to liquid, Th(L), always require correction for hysteresis of Th(L) due to surface tension of the liquid-vapor interface. Thermodynamic analysis of the phenomenon demonstrates that this hysteresis (and hence the "correction" to compensate for it) may range from tens of degrees (in low-T geologic environments) to an immeasurably small fraction of a degree (for Th(L) near the fluid's critical point), depending on the *size*, composition, and actual density of the FI. Available data on the surface tension of fluids permit accurate description of Th(L) hysteresis in pure H_2O and CO_2 inclusions as a function of FI volume and fluid density. A new, theoretically based corresponding-states algorithm allows experimental values of the surface tension of H_2O-NaCl solutions in the range 0-6 molal and 10-50°C to be reproduced accurately and extrapolated reliably to about 200°C. These experimental and predicted values of the surface tension of NaCl brines are used to evaluate the hysteresis of Th(L) in NaCl-H_2O fi's over the range of fluid density and inclusion size in which the hysteresis is of practical significance. (Author's abstract)

LOWENSTEIN, T.K., SPENCER, R.J. and **CASAS, Enrique**,1989, Melting/dissolution behavior of fluid inclusions in halite: Application to natural deposits (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 44. First author at Dept. Geol. Sci., S.U.N.Y. Binghamton, Binghamton, NY 13901.

FI trapped in halite crystals in evaporite deposits contain samples of: (1) syndepositional surface brines in FI-banded "chevron" and "cumulate" halites, and (2) diagenetic brines in clear halite cements and displacive halite. The chemical composition of these FI may be determined based on observation of T of melting/dissolution of solid phases. FI in halite may also be used to establish the timing and mechanisms of potash mineralization in ancient evaporites.

FI ion Holocene-Pleistocene halites (depths of 0-43 m) from the Qaidam Basin of western China carry a continuous record of brine compositions and brine evolution over the past 25,000 years. FI compositions are determined based on Tm ice and Tm hydrohalite in the ternary NaCl-$MgCl_2$-H_2O system, using a specific ion interaction solution model to low T (down to -60°C). The NaCl-$MgCl_2$-H_2O) ternary is used because modern surface and groundwater brines in the area studied contain Na + Mg = 90-97% total cation molality and Cl = 99% total anion molality. The basal subaqueous chevron halites (depth greater than 40 m) contain FI that are relatively dilute and low in Mg (m = 0.4). Calculated brine compositions from the top 10 m thick potash salt-bearing interval contain 1.1-2./5 m Mg with large fluctuations in brine concentration over short stratigraphic intervals. This is consistent with petrographic textures of halites which indicate precipitation in a shallow saline lake and saline pan setting.

Determination of the major element composition of syndepositional brines (system Na-K-Mg-Ca-Cl-SO_4) trapped in chevron and cumulate halites from the Oliogocene Rhine Graben (Alsace, France), the Permian Salado Formation (New Mexico), and the Devonian Prairie Formation (Saskatchewan) has been done using various combinations of FI data (Tm sylvite, hydrohalite, ice, and $MgCl_2 \cdot 12H_2O$), petrographic data (saturation with respect to gypsum, anhydrite, or polyhalite), saturation with halite at the Tt, and a charge balance equation. The calculated compositions may be used to test models involving seawater inflow, non-marine inflow, and mixed seawater-non-marine parent waters.

FI in subaqueous chevron and cumulate halite associated with potash salts from the Rhine Graben, Salado and Prairie evaporites contain dxls of sylvite. This establishes the existence of surface brines capable of precipitating sylvite without further concentration. Sylvite dxls from FI in halite dissolve at moderately high T (average of 63°C for Rhine Graben; 71°C for Salado; and up to 61°C in the Prairie). Tm sylvite indicate that halite crystallized from warm surface brines, rich in KCl. Cooling of these brines at or just below the surface is a major mechanism by which to achieve supersaturation with respect to sylvite. (Authors's abstract)

LOWENSTEIN, T.K., SPENCER, R.J. and **PENGXI, Z.,** 1989, Origin of ancient potash evaporites: Clues from the modern nonmarine Qaidam Basin of western China: Science, v. 245, p. 1090-1092. First author at Dept. Geological Sciences and Environmental Studies, State Univ. New York at Binghamton, Binghamton, NY 13901.

Modern potash salt deposits and associated brines of the Qaidam Basin, western China, demonstrate that some anomalous marine evaporites may have formed from nonmarine brines instead of seawater. Qaidam Basin brines are derived from meteoric river inflow mixed with small amounts of Ca-Cl spring inflow similar in composition to many saline formation waters and hydrothermal brines. Evaporation of spring-enriched inflow yields a predicted mineral sequence including carnallite, bischofite, and tachyhydrite that is identical to several anomalous marine evaporites. Other mixtures of river and spring inflow produce the salt assemblage expected from evaporation of seawater. (Authors' abstract)

LOWRY, D., BOYCE, A.J., FALLICK, A.E. and **STEPHENS, W.E.,** 1989, Sulphur isotope systematics of late Caledonian granitoid-related mineralisation in the N.W. Highlands of Scotland (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 31. First author at Dept. Geology, Univ. St. Andrews, St. Andrews, Fife, Scotland.

Extensive S isotopic analyses on vein and disseminated S species in Dalradian- and Moinian-hosted Late Caledonian granitoids have revealed two distinct isotopic provinces, the boundary being the Great Glen Fault. Disseminated and vein mineralisation in granitoids to the S.E. are characterised by values of δ^{34}S from -1 to +5‰ whereas disseminated mineralisation to the N.W. has a range from -5 to -1‰. The vein mineralisation related to granitoids in the N.W. Highlands is characterised by base-metal sulphides, fluorite and sulphates, as distinct from the quartz-sulphide-carbonate dominated systems in Dairadian-hosted granitoids. δ^{34}S values for the veins range from -21 to 0‰ for the sulphides and +7 to +17‰ for the sulphates. Derivation at relatively high fO_2 conditions from a magmatic fluid is proposed.

A closer examination of quartz veining in the roof zone of the Lower Loch Shin monzogranite and fluorite-barite veining around the Eastern margin of the Grudie monzogranite shows that there is a progressive lightening of sulphide mineral δ^{34}S with paragenetic sequence, a corresponding increase in importance of SO_4 with time, and the presence of quartz and hematite in later stages of mineralisation. Although there is no direct evidence for precipitation of minerals in isotopic and chemical equilibrium, isotopic equilibrium T of 291-211°C for sulphate/sulphide pairs are in agreement with P fluid inclusion T from coexisting fluorite of 320-240°C. Modelling of H_2S values for the fluid using S isotopic equilibrium T was carried out using this evidence. The variations calculated at Grudie are from -1‰ for early disseminated pyrite, through -15‰ at the onset of sulphate mineralisation, down to -18‰ for galena co-existing with barite. A δ^{34}S ‰ vs. Δ sulphate-sulphide plot for co-existing barite-galena pairs indicate an initial H_2S value of ~-1% for the fluid, a value close to that of early disseminated pyrite, and a sulphate:sulphide ratio close to 3:2. The $\delta^{18}O(SO_4)$ values of barite, +10.5 to +12‰, are calculated to be in equilibrium with $\delta^{18}O(H_2O)$ values of primary magmatic waters (+5.5 to +10‰) at the T under consideration.

A magmatic fluid with relatively high fO_2 and an initial δ^{34}S value ~-1‰ is proposed for primary mineralisation in granitoid-related veins at Grudie, Loch Shin and Ratagan. As the system evolved, the δ^{34}S value of H_2S became gradually lighter and SO_4 became an important species. The Lewisian is seen as a potential component of the granitoid magmas in this region. The presence of a zone of plutons of monzonitic affinity along the Ratagan-Helmsdale line with Au mineralisation seen at each end suggests that intrusives of this type having sulphides with negative δ^{34}S values and a CO_2-dominated P fluid inclusion population, as at Ratagan, can be used as tools in the search for further Au mineralisation within this region. (Authors' abstract)

LU, Changsheng and REED, M.H., 1989, Computer modelling of skarn-forming reactions—The skarn mineral assemblages and effect of salinity and sulfur concentration of fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A237.

LU, Fangqiong, DAVIS, A.M., SKIRIUS, C.M. and ANDERSON, A.T., Jr., 1989, Significance of uranium variations in rhyolitic melt inclusions from the Bishop Plinian and early ash-flow deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A271. Authors at at Dept. Geophysical Sciences, Univ. Chicago, Chicago, IL 60637.

Forty-six glass inclusions in 25 quartz phenocrysts in the Bishop Tuff have been analyzed by ion microprobe to determine trace element concentrations. The quartz phenocrysts were separated from pumice lumps from selected stratigraphic levels in Plinian and earliest ash-flow deposits. Major element concentrations within the glass inclusions are constant and indistinguishable (except for Fe and Ca) from reported bulk rock and glass compositions. U concentrations vary by a factor of 1.83 (maximum/minimum), whereas Na and K both vary by a factor of only 1.16. The U concentrations are skewed toward the low end of the range. Comparable U variations occur between inclusions within individual crystals and from crystal to crystal and lump to lump. Reentrant glass and inclusions near crystal rims are higher in U than interior inclusions. There is no conspicuous trend with stratigraphic position. Ten inclusions from a single lump of pumice form a tight negative correlation between U and La. Groups of inclusions from some other pumice lumps yield distinct negative correlations between U and La.

U is a highly incompatible element in high-silica rhyolitic magma and is characterized by a bulk crystal/melt distribution factor of about 0.06. This is consistent with the core to rim trends for inclusions within individual crystals. In addition, the U contents of most inclusions fall between reported values for bulk Plinian pumice and matrix glass. However, some inclusions have U concentrations significantly greater than reported for Plinian glass. Although systematic analytical bias may contribute to this difference, the within-sample variability is much larger than can be accounted for by closed system crystallization of the observed 15 wt % of phenocrysts. The similarity of major element concentrations within the glass inclusions and bulk rock and glass rules out significant diffusional control of trace element concentrations. Some form of crystal/liquid separation must have occurred, because the glass inclusions are derived from a system larger than the bulk rock or individual pumice lump. Perhaps some quartz crystals were derived from small regions that were more extensively differentiated than the matrix glass in which they now occur. Loss of crystals may have occurred during differentiation but cannot explain why some glass inclusions enclosed in quartz are more differentiated than matrix glass. The bulk solid/liquid distribution factor for La inferred from its relationship with U is consistent with data on La partitioning between allanite and rhyolite liquid and on the model proportion of allanite in Bishop pumices (Hildreth, 1979, GSA Special Paper 180, 43-75). Variable La at a fixed value for U can be explained by uneven equilibration (as opposed to fractionation) between allanite and melt. The Bishop Plinian pumices evidently contain some crystals derived from separately fractionated environments. (Authors' abstract)

LUETH, V.W., PINGITORE, N.E., Jr. and GOODELL, P.C., 1989, Characterization of telluride mineralization in the Organ District, New Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A149. First author at Dept. Physical Sciences, Tarleton State Univ., Stephenville, TX 76402.

Tellurides occur in two distinct types of mineralization: (1) base metal sulfide mantos and (2) quartz vein and breccia bodies with fluorite, sulfides, and tellurides. Although the deposit types are distinct, they appear related to the same mineralizing system.

The mineralization is strongly controlled by structure. A fault which intersects the Organ Porphyry system appears to be the main conduit of ore fluids (indicated by metal ratio zoning). The manto deposits are then localized by small anticlinal flexures on a larger homoclinal structure. All mantos are confined to dolomite units directly beneath the Percha Shale which acted as an impermeable barrier to the ascending fluids. Quartz vein and breccia deposits are localized in the main fault, subsidiary cross faults and beneath some of the mantos.

Petrologic relationships between the two types of mineralization are complex. Upper portions of the manto contain no tellurides, and lower portions contain altaite and rare rickardite in proximity to quartz mineralization. The quartz ores display a paragenetic sequence of galena-altaite-native tellurium, indicating increasing Te activity. Precious metal tellurides are rare (hessite micro-inclusions in galena), and native Au is present in wall zones. Quartz fluid inclusion Th populations overlap, although mean T in manto ores (Th = 206°C) are higher than quartz ore bodies (mean

Th = 178°C). Telluride occurrences in the mantos appear to be overprinted by the later quartz-telluride event. (Authors' abstract)

LUKERCHENKO, V.N., 1989, Thermodynamics of plastic deformation of solid crystalline bodies: Doklady Akad. Nauk SSSR, v. 308, no. 2, p. 298-303 (in Russian). Author at Moscow State Univ., Moscow, U.S.S.R.

Pertinent to theory of inclusion stretching and decrepitation. (A.K.)

LUPTON, J.E., BAKER, E.T. and MASSOTH, G.J., 1989, Variable ^{3}He/heat ratios in submarine hydrothermal systems: Evidence from two plumes over the Juan de Fuca ridge: Nature, v. 337, p. 161-164.

LUTH, R.W., 1989, Natural versus experimental control of oxidation state: Effects on the composition and speciation of C-O-H fluids: Am. Mineral., v. 74, p. 50-57. Author at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008, USA.

In high-P, solid-media apparatus, the oxidation state of a sample is usually controlled by imposing a known H fugacity (fH_2) on the system. The oxidation state of natural systems, in contrast, is often defined by an internally or externally fixed O fugacity (fO_2). This contrast has fundamental implications for the application of experimental results to natural systems containing C-O-H fluids (Eugster and Skippen, 1967).

The composition and speciation of a C-O-H fluid were calculated for a given P, T, and either an imposed fH_2 or an imposed fO_2. The requisite fugacity coefficients were calculated with the modified Redlich-Kwong equation of state (MRK Eos) of Holloway (1977, 1981). Comparison of the composition and speciation of the fluid calculated with the two sets of constraints illustrates the differences between the imposed-fO_2 and the imposed-fH_2 cases.

The solidus of $NaAlSi_3O8$(Ab)-C-O-H, with fH_2 buffered by Ni-NiO-H_2O (NNO, OH) was experimentally determined at 10 and 15 kbar to constrain the calculations of the composition and speciation of the fluid. The T of the solidus of this system is lower than that of Ab-CO_2 by ~90°C and ~170-°C at 10 and 15 kbar, respectively. With the fH_2 fixed by the NNO buffer, the fluid coexists with graphite, and contains 77% CO_2, 16% H_2O, 6.6% CO, and <1% CH_4 and H_2 at 10 kbar and 69% CO_2, 28% H_2O, 2.4% CO, and <1% CH_4 and H_2 at 15 kbar at the T of the solidus. The predominance of H_2O and CO_2 in the NNO-buffered fluid allows comparison of these results with previous experimental data for the solidi of Ab-CO_2-H_2O having known values of $CO_2/CO_2 + H_2O$) in the fluid (Bohlen et al., 1982). This comparison suggests that the calculated fluid compositions are too H_2O-rich.

To achieve fluid compositions with values of fO_2 near those of the quartz-fayalite-magnetite (QFM) buffer, as proposed for many regions of the lower crust and upper mantle, the oxidation state of an experiment that contains a mixed-volatile fluid must be controlled by a buffer that has a higher value of fO_2 than does QFM, because of the imposition of fH_2 rather than fO_2 on the sample. Furthermore, the fO_2 of the buffer required to maintain the fO_2 of the sample at QFM increases with decreasing $X(H_2O)$ in the vapor; such continuous variation in the fO_2 of the buffer required to maintain a constant fO_2 of the sample is not attainable with present experimental applications of the fO_2 buffers. (Author's abstract)

LUTH, R.W. and MUNCILL, G.E., 1989, Fluorine in aluminosilicate systems: Phase relations in the system $NaAlSi_3O_8$-$CaAl_2Si_2O_8$-F_2O_{-1}: Geochim. Cosmochim. Acta, v. 53, p. 1937-1942. First author at Bayerisches Geoinstitut, Univ. Bayreuth, Postfach 10 12 51, D-8580 Bayreuth, F.R.G.

The liquidus phase equilibria of 0.9 $NaAlSi_3O_8$-0.1$CaAl_2Si_2F_8$-F_2O_{-1} was determined to 10 kbar for a composition with molar F/(F + O) = 0.095. The T of the liquidus is depressed by ~200°C at 1 bar, 2 kbar, and 10 kbar, relative to the volatile-free liquidus. Additional experiments were carried out at 2 kbar to examine the effects of increasing F content on phase equilibria. Increasing molar F/(F + O) to 0.156 at fixed P decreases the T of the liquidus ~350°C from the T of the volatile-free liquidus.

The effect of F is in marked contrast to that of H_2O, which has little effect on the composition of the plagioclase in equilibrium with a melt of given (anhydrous) composition. Because of this, the degree of plagioclase fractionation in a F-bearing, anhydrous system would be in considerable excess of estimates based solely on the F-free anhydrous albite-anorthite system or the H_2O-saturated albite-anorthite-H_2O system. Rigorous application of these results to fractionation in late-stage, felsic systems will require additional experiments on the combined effects of H_2O and F in Ca-bearing granitic systems. (From authors' abstract by E.R.)

LYASHKEVICH, Z.M., MARUSHKIN, A.I. and TKACH, V.N., 1989, Inhomogeneity of volcanic glass and origin of amygdules in basalts: Doklady Akad. Nauk SSSR, v. 308, no. 5, p. 1204-1207 (in Russian). First author at Inst. Geology and Geochemistry of Mineral Fuels of Ukraine Acad. Sci., L'vov, Ukraine, U.S.S.R.

The montmorillonite-filled amygdules in basalt are interpreted as altered product of silicate-silicate immiscibility. (A.K.)

LYNCH, J.V.G., 1989a, Hydrothermal zoning in the Keno Hill Ag-Pb-Zn vein system: A study in structural geology, mineralogy, fluid inclusions, and stable isotope geochemistry: PhD dissertation, Univ. Alberta, Edmonton, Alberta, Canada.

High grade Ag-Pb-Zn veins of the Keno Hill district, in central Yukon, occupy sinistral strike-slip faults which formed in association with a broad region of upright shear, overprinting an earlier thrust system. Faults, fractures and veins are lithologically restricted to the graphitic Keno Hill Quartzite unit of Mississippian age. Hydrothermal veining is continuous for 40 km, and is contemporaneous with the Mayo Lake Pluton (81 Ma). Zoning is characterized by quartz-feldspar veins near the pluton, carbonate-Ag-Pb-Zn veins further away, and peripheral deposits of epithermal character.

In the mining district, FI were studied from early quartz, and from later siderite which is intergrown with the principal ore assemblage of galena, sphalerite, and tetrahedrite. The dominant components of the fluids are H_2O-CO_2-NaCl in varying proportions. Fault-related depressurization, from ~1500 bars during deposition of early quartz to less than 130 bars during deposition of siderite, resulted in boiling and cooling of the fluids from near 310°C, to 250°C, as well as a decrease in CO_2 from $XCO_2 = 0.25$ to <0.01. Graphite in the host rocks had a strong influence on the system, buffering the fluids to a high CO_2 content and allowing for deep seated boiling to occur. Syn- to post-boiling reactions between graphite and water resulted in high salinities for inclusions in siderite (10 to 15 wt % NaCl eq.).

$\delta^{18}O$(SMOW) values from vein quartz (+10.6 to +20.0‰) indicate that the fluids were largely in equilibrium with the quartzite. Contours of these values outline paths of fluid movement along the 40 km long system. In the mining district $\delta^{18}O$(quartz) from Ag-rich deposits is relatively high due to boiling-related cooling, whereas trends of ^{18}O depletion in siderite resulted from post-boiling CO_2 formation. Carbon isotopes in vein carbonates ($\delta^{13}C$(PDB) = -12.9 to -4.0‰) indicate a reduced carbon source. Meteoric water and mixing are indicated in the late epithermal deposits ($\delta^{18}O$(SMOW) for quartz = +10.1 to -7.1‰). (Author's abstract)

LYNCH, J.V.G., 1989b, Hydrothermal alteration, veining, and fluid-inclusion characteristics of the Kalzas wolframite deposit, Yukon: Can. J. Earth Sci., v. 26, p. 2106-2115. Author at Geol. Surv. of Canada, Cordilleran Div., 100 West Pender St., Vancouver, B.C. V6B 1L5, Canada.

Kalzas is a sheeted vein and stockwork wolframite deposit, crosscutting continental margin sedimentary rocks of the Proterozoic Windermere Supergroup in central Yukon. Mineralization is synchronous with Cretaceous post-tectonic granites of the Selwyn Plutonic Suite.

Parallel sets of planar quartz veins contain coarse euhedral wolframite and are generally oriented perpendicular to southeast-plunging fold axes. Widespread alteration of the host rocks and intense stockwork veining surround the veins. Alteration and mineralization show a distinct concentric zonation across a 2.5 km long southeast-trending oval. The core zone is characterized by orthoclase contained within quartz-tourmaline-wolframite veins. Minor phases include apatite, molybdenite, bismuthinite, pyrite, chalcopyrite, and pyrrhotite. Host rocks are pervasively tourmalinized and sericitized. Hydrothermal alteration here at the core of the system overprints early biotitization of the host rocks. The biotitization appears to have been the result of earlier contact metamorphism from a hidden pluton situated beneath the deposit that converted the chloritic groundmass of the metasediments to biotite. At the fringe of wolframite mineralization, cassiterite occurs with quartz, muscovite, and tourmaline, whereas orthoclase is distinctly lacking. The outer periphery of the concentrically zoned sequence features pervasive sericitization, disseminated pyrite, and the disappearance of tourmaline. Here, quartz veins are barren except for minor galena.

Three main stages mark the mineralogical evolution of the deposit: (1) early biotitization of the chloritic host rocks in the core area; (2) quartz-dominated veining with internally complex timing relations, hydrothermal alteration, and zoning; and (3) carbonate veining and replacement of wolframite by scheelite.

FI within quartz are dominated by H_2O and contain variable amounts of CO_2 as well as minor CH_4 and NaCl. The CO_2 content ranges from ~0 to 6 mol %. The fluids are generally dilute but locally contain as much as 7 wt % NaCl eq. Th are variable: for quartz, 160-340°C; for cassiterite, 280-350°C; and for apatite, 220-360°C. Minimum hydrothermal P at the time of mineralization are estimated to have been in the range 300-600 bar (1 bar = 100 kPa). Fluctuations in P with cooling appear to have resulted in CO_2 immiscibility and the formation of late-stage carbonates at the termination of hydrothermal activity. (From author's abstract)

LYOVIN, K.A. and **ZOTOV, A.V.**, 1988, Silver precipitation under hydrothermal conditions (thermodynamic analysis): Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 41 (in Russian). Authors at Inst. Geol. of Ore Deposits, Petrography, Mineralogy and Geochem. of Acad. Sci. of U.S.S.R., Moscow, U.S.S.R. (abst.).

MacFARLANE, A.W., 1989, Lead, sulfur and strontium isotopes in the Hualgayoc area, Perú, and lead isotope provinces of the central Andes: PhD dissertation, Dept. Earth and Planetary Sciences, Harvard Univ., Cambridge, MA, 374 pp.

The Hualgayoc District is a typical Pb-Zn-Cu-Ag mining district in the Andean Cordillera having coexisting stratabound and vein deposits. Ion probe analyses of Pb isotopes in vein and manto galena indicate a common Pb source. The slight variations in traverses across growth zones of vein galenas indicate little mixing of ore Pb sources. Pb isotope analyses of ores, associated plutons, sedimentary host rocks and metamorphic basement show that the Miocene plutons provided the ore Pb. Sr and Pb isotopes show little evidence for assimilation of upper crustal rocks by the magmas, and suggest an enriched upper mantle source region.

The manto ores correspond paragenetically to the earliest vein mineralization. Fluid inclusion Th and Tm data show that the manto ore fluids had Th = 300 ± 40°C and average NaCl eq. salinities of ≈12 wt %. Inclusions from early vein stages yield Th ≈ 250 ± 15°C and highly variable salinities. Late-stage vein inclusions cluster at Th ≈ 150 ± 15°C and salinities of ≈6.5 wt %. Manto ores formed by early, high-T replacement of porous sedimentary rocks, whereas the veins represent later infilling of the fluid conduits as the system cooled, possibly due to dilution with meteoric waters. Rb/Sr data on late vein gangue minerals reflect Sr from the host sediments.

Sulfur isotope ratios of pyrite and galena measured by ion probe suggest a magmatic source for most vein and manto sulfides. $\delta^{34}S$ of most manto sulfides range between -5 and 7‰. Pyrite and galena in veins contain sulfur that is 4-5‰ lighter than in manto ores, and decrease in $\delta^{34}S$ with time. This may result from mixing with sulfur from diagenetic sulfides or from oxidation of the ore fluid in the later vein stages.

The Central Andes comprise three major geological provinces. Province I is dominated by the Coastal Batholith and associated volcanic rocks, province II by Mesozoic shelf sediments overlying low-grade metamorphic basement rocks and province III by a thick prism of lower Paleozoic shales. Ore Pb from these provinces define separate isotopic fields. Ore Pb from provinces I and II reflect different degrees of mixing of Pb from a relatively homogeneous enriched upper mantle source with isotopically diverse shallow crustal sources. More variable and radiogenic ore Pb indicate that crustal fusion was important in the genesis of province III magmas and ore deposits. (Author's abstract)

MacGOWAN, D.B. and **SURDAM, R.C.**, 1989, Mobilization of metals by organic complexation during clastic diagenesis (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-344.

MacPHERSON, G.L. and **LAND, L.S.**, 1989, Bromide in Gulf Basin formation waters: Organics as an additional source (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A316.

MAEDA, Hiroyuki and ITO, Yoji, 1989, Bismuth-bearing minerals from the Inakuraishi ore deposits, southwestern Hokkaido, Japan: Mining Geol., v. 39, no. 3, p. 223-229. Authors at Dept. Developmental Engineering, Faculty of Engineering, Kitami Inst. Technology, Kitami 090, Japan.

Two bismuth minerals, gustavite and "bismuthinite," were newly found in an ore from an outcrop of the Taisei vein, Inakuraishi mine. The ore occurs in strongly altered andesite as veinlets less than 5 cm in width and was cut by a Mn oxide vein, 10 to 20 cm in width. The Mn oxides were estimated to have formed by weathering of hydrothermal Mn carbonates. Vein minerals are quartz, pyrite, and chalcopyrite with accessory amounts of gustavite, "bismuthinite," galena, acanthite, sphalerite, hematite, and marcasite. The gustavite and "bismuthinite" occur in close association with each other, but they do not coexist with galena or acanthite which contains a few wt % Bi. The possible T and sulfur fugacity during deposition of the bismuth minerals are estimated to be in ranges of 254° to 280°C and $10^{-11.1}$ to $10^{-9.3}$ atm, respectively. These data suggest that the bismuth minerals had formed at stage II of the Inakuraishi mineralization. (Authors' abstract)

Th (Table 3) ranges from 160--280°C. (E.R.)

MAKJANIC, J., TOURET, J.L.R., VIS, R.D. and VERHEUL, H., 1989, Carbon in glass inclusions in the Allende meteorite: Meteoritics, v. 24, p. 49-55. First author at Dept. Physics and Astronomy, Free Univ., Amsterdam, The Netherlands.

Olivines in chondrules of the Allende CV3 carbonaceous chondrite contain two types of micron sized silicate melt inclusions: clear glass (type I) and devitrified glass (type II) inclusions. Many of the type I inclusions contain a gas bubble of variable size. Type II inclusions can be transparent (IIa), with or without a gas bubble, and brown (type IIb), with a gas bubble.

A number of inclusions were measured with the Raman microprobe to detect possible presence of carbon. Carbon in the form of graphite was detected only in type II inclusions. Compositions of 11 inclusions were determined with the electron microprobe and proton microprobe in search for possible explanation of this preference of carbon for devitrified inclusions. All of the measured inclusions are rich in Si, Al and Ca. No significant differences between the compositions of the two types of inclusions were found. The data suggest that the inclusions formed from the melt trapped in growing olivine crystals, which themselves crystallized from a silicon-rich, gas-bearing melt. There is no coherent relation between the occurrence of graphite and the gas abundance in the original melt, as indicated by the sizes of gas bubbles. Therefore, carbon was not combined in a gaseous species (e.g., CO). It must have been preferentially dissolved in some domains of the melt. (Authors' abstract)

MANGAS, J., 1989a, A fluid inclusion study of the Penouta tin deposit, Orense, Spain (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 63.

The Penouta deposit is associated with a small Hercynian apogranite stock that intrudes Precambrian-Cambrian gneisses of the Ollo de Sapo Formation. Tin ore occurs as disseminations of cassiterite in the apogranite and as greisenized zones and quartz veins which traverse both the alkaline leuco-granite and the adjoining metamorphic rocks.

A FI study, utilizing microthermometric and Raman spectroscopic techniques on quartz from an intragranitic vein (P 34) and a greisen of the host rock (P 115), indicates that the hydrothermal evolution of the fluids was similar in both samples and occurred in three main stages. The first stage is characterized by the entrapment of complex CO_2 (CO_2-CH_4-N_2-H_2S) and complex CO_2-aqueous fluids (H_2O-NaCl-CO_2-CH_4-N_2) of low salinity (Tm ice > -6°C) at minimum T between 250 and 410°C. These fluids were probably responsible for the precipitation of cassiterite. The second stage is represented by low-salinity aqueous solutions (H_2O-NaCl) with Tm ice > -4.5°C, trapped at Th between 110 and 300°C. The third stage is characterized by higher salinity aqueous fluids (Tm ice > -17°C) containing other cations in addition to Na^+, trapped at Th between 100 and 130°C. (Author's abstract)

MANGAS, J., 1989b, Fluid inclusion studies as tools in mineral exploration of tin and tungsten deposits associated with the Hercynian granites of western Spain (abst.): XIII Int'l Geochemical Exploration Symposium, Abstracts, Brazilian Geochemical Congress, p. 48-49. Author at Dept. Geology, Faculty of Marine Sciences Polytechnical Univ. of Canary Islands, Spain.

For fluid inclusion data, see Mangas and Arribas, 1987a, in Fluid Inclusion Research, v. 20, p. 254. (E.R.)

MANGAS VIÑUELA, José and **ARRIBAS MORENO, Antonio,** 1989, Study of fluid inclusions trapped in cassiterite and quartz crystals of San Finx deposit (La Coruña, Spain): Bóletin de la Sociedad Española de Mineralogía, v. 12, p. 241-259 (in Spanish, English abstract). First author at Dept. Geología, Facultad de Ciencias del mar. Univ. Politécnica de Canarias, Apdo. 550. 35016 Las Palmas de Gran Canaria.

Microthermometry and crushing tests in anhydrous glycerine were the two analytical techniques used to characterize the fluids that accompanied the precipitation of the cassiterite. Based on these studies, the thermobarogeochemical evolution of the fluids trapped in the samples studied could be divided into three stages.

The *first* stage is characterized by weakly saline aqueous solutions with volatiles, at Th ranging between 330 and 220°C. These fluids have salinities <6 eq. wt % NaCl, and densities varying from 0.7 to 0.85 g/cc. The Sn could have been transported in these aqueous solutions as chloride, hydroxide and carbonate complexes. The *second* stage is characterized by weakly saline aqueous solutions, at Th varying between 220 and 150°C. The salinity of the fluids is <6 eq. wt % NaCl, and densities range between 0.85 and 0.95 g/cc. The *third* stage is represented by aqueous solutions of higher salinity, with cations Ca^{++}, Mg^{++}, Na^{+} and K^{+}, with Th ranging between 170 and 90°C. These solutions present estimated salinities >7 eq. wt % NaCl, and densities ranging from 0.95 [to] 1.15 g/cc. (Authors' abstract)

MANGO, F.D., 1989, The thermal stability of sedimentary hydrocarbons at very high subsurface temperatures (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A48. Author at Shell Development Co., P.O. Box 481, Houston, TX 77001.

The hydrocarbons found in petroleum are believed to be thermally unstable above ~150°C. Above this T, liquid petroleum is alleged to decompose to natural gas and graphite. The steranes and triterpanes are thought to be particularly unstable and thus decompose at the early stages of catagenesis, yielding the light cycloalkanes between C_5 and C_9.

The polycyclic nucleus of the steranes and triterpanes is shown to be remarkably stable with respect to thermal decomposition. For example, the bicyclodecyl unit decalin has a half-life of ~35 b.y. at 150°C. In the presence of organosulfur compounds typically found in petroleum or hydrogen donor compounds like tetralin, the thermal stability of these hydrocarbons is even greater.

These results are not consistent with current views on the thermal stability of hydrocarbons in the subsurface. They suggest that hydrocarbon fossils could survive subsurface T very much higher than previously thought. (Author's abstract)

MANGO, H.N., 1989, The Guanajuato Ag-Au-Cu-Pb-Zn district, Mexico: Fluid inclusion analysis (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A149-150. Author at Dept. Earth Sciences, Dartmouth College, Hanover, NH 03755.

The analysis of fluid inclusions from mines across the Guanajuato mining district in central Mexico shows vertical and lateral variations in fluid salinities and T. Four mines, Rayas and Torres on the central Veta Madre, Bolañitos on the La Luz vein system to the northwest, and Peregrina on the Sierra vein system to the southeast, were chosen for this part of an ongoing study of the Guanajuato district. Heating/freezing analysis of fluid inclusions in quartz and calcite suggests that low-salinity fluids of moderate T were responsible for ore deposition. The results are as follows:

mine	average Th	average salinity	average elevation
Rayas	268°C	1.2 wt % NaCl eq.	1750 m.a.s.l.
Torres	260°C	1.2 wt % NaCl eq.	2100 m.a.s.l.
Peregrina	243°C	1.5 wt % NaCl eq.	2100 m.a.s.l.
Bolañitos	175°C	0.8 wt % NaCl eq.	2200 m.a.s.l.

(m.a.s.l. = meters above sea level)

Bolañitos, at the highest elevation, contains inclusions of fluids of the lowest salinity. Bolañitos and Peregrina, at the edges of the district, show the lowest T. Rayas, at the lowest elevation, contains evidence of the hottest fluids. The deeper portions of Rayas contain significantly richer precious and base metal mineralization than the other three mines. This deep ore has fluid inclusions of relatively high salinities (average = 1.5 wt % NaCl eq.) and T (average = 274°C).

The trend of decreasing Th with decreasing depth and increasing lateral variation at all four mines, is consistent with a model of metal deposition due to an influx of cool, dilute meteoric water, and suggests that the whole district was mineralized by one hydrothermal system, centered at Rayas. Upcoming fluid inclusion and isotopic research will further define the nature and effects of the hydrothermal fluids in Guanajuato. (Author's abstract)

MEGAW, P.K.M., 1989, Sulfur isotope geochemistry of the Santa Eulalia mining district, Chihuahua, Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A150. Author at Dept. Geosciences, Univ. Arizona, Tucson, AZ 85721.

Mineralization at Santa Eulalia occurs in the West Camp (WC) as massive sulfide ores (MS) and in the East Camp (EC) as sulfide-rich skarn (SK), hosted in a thick section of limestone underlain by pyritic black shale and anhydrite. The sulfides in both areas consist of galena (gn), sphalerite (sp), and pyrrhotite (po) with local pyrite (py). Fluid inclusions in MS and SK yielded uncorrected Th of 250-450°C from both hypersaline and dilute fluids.

Sulfur isotope analyses (presented in permil relative to CDT) were performed on four sedimentary rocks and 79 ore sulfide samples with the following results: black shale pyrite (-28); anhydrite (+15.6); EC-SK (-13.5 to +4.5); WC-MS (bimodal: -17.5 to -13 and -13 to -6.5). Sp and po are lighter than in 18 of 20 gn-sp and gn-po pairs. Eight pairs yielded calculated T of 250-475°C. There is no systematic isotopic difference between po-bearing and py-bearing mineralization, nor is there a correlation between sulfur isotopes and fluid inclusion T, salinity, ore type, or metals ratios. Sulfur isotopic zoning is crude in the WC and absent in the EC.

The predominance of po and T of 250-450°C indicates mineralization occurred under reduced conditions, at low pH, in the H_2S-dominant field. Coupled with the sulfur isotope ranges of 20‰ and isotopic disequilibrium, the data indicate: multiple S sources; relatively S-poor fluids; and that the fluids must have acquired their S outside the site of mineralization.

Mass balance calculations indicate that incorporation of varying proportions of S from anhydrite and black shale pyrite to a metals-rich saline fluid can account for the patterns and variations seen throughout the district. (Author's abstract)

MANIER-GLAVINAZ, V., D'ARCO, P. and LAGACHE, M., 1989, Alkali partitioning between beryl and hydrothermal fluids: An experimental study at 600°C and 1.5 kbar: European J. Mineralogy, v. 1, no. 5, p. 645-655.

MANNING, C.E. and BIRD, D.K., 1989, Porosity evolution: A guide to the hydrology of contact aureoles (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A83.

MANNING, D.A.C., 1989, Base metal transport in composite petroleum-brine systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-362.

MARARITZ, M., KAUFMAN, A., PAUL, M. and BOARETTO, E., 1989, ^{36}Cl geochemistry of the brines in the Magadi-Natron Basin, East Africa (abst.): Eos, v. 70, p. 1102.

MARIGNAC, Ch., BENNANI, M., BOUTALEB, M. and WEISBROD, A., 1989, Geochemical evolution of the hydrothermal fluids associated with the Walmes Sn-W deposit (Central Morocco), from fluid inclusion data (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 64. First author at CRPG, Nancy, France.

In central Morocco, the Walmes granitic pluton intrudes very low grade Cambro-Ordovician schists and quartzites. It is a multi-stage intrusion: (1) El Karit biotite granite (γEk), (2) main two-mica granite (γp), (3) two-mica granite porphyry (γπ), and (4) muscovite granites and aplite.

Several stages of hydrothermal circulation are responsible for hydrothermal alteration of the meatmorphites and granites, and mineral deposition in and around the pluton, these are: (i) very early boron-rich fluids, associated with γEk (tourmaline ± quartz); (ii) early fluids associated with γp (main quartz veins, in the schists); (iii) Sn-mineralizing fluids, associated with $\gamma\rho$ to late $\gamma\pi$ emplacement (muscovite, cassiterite ± beryl ± apatite; alternate quartz deposition and dissolution); (iv) W-mineralizing fluids (muscovite, wolframite-ferberite ± quartz) followed by sulphide depositing fluids (arsenopyrite, quartz); and (v) late, "cold" post-magmatic fluids.

The major results, mainly obtained from microthermometry and Raman spectroscopy, are as follows: (i) fluid salinities were initially very low (<2 wt % eq. NaCl); there is no indication of a magmatic contribution; (ii) all the fluids involved have significant contents of volatiles (CO_2, CH_4, N_2). In the early fluid, the composition of these volatiles are very variable and almost all combinations between the three end members have been observed; (iv) the fluids responsible for Sn-Be-Al transport were quartz undersaturated; and (v) the fO_2 during the hydrothermal evolution is controlled by the graphite-fluid equilibrium, and decreases from 10^{-20} at 600°-650°C to 10^{-32} at 300°C. However the fO_2 during the ferberite deposition is significantly lower (10^{-33} to 10^{-34}).

In conclusion, most of the COHN fluids involved in the Walmes hydrothermal system are of metamorphic derivation. Their dilution and cooling, as well as the increase of the redox conditions, are responsible for the mineral deposition. (Authors' abstract)

MARKUS, R.S. and **BAKER, D.R.**, 1989, Sulfur solubility in anhydrous andesitic melts (abst.): Eos, v. 70, p. 1402.

MARSHALL, D.D., SKIPPEN, G.B. and **DIAMOND, L.W.**, 1989, Fluid inclusion evidence for the composition and state of the hydrothermal solutions in the silver veins at Cobalt, Ontario (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-121. Authors at Dept. Earth Sci., Carleton Univ, Ottawa, Ontario K1S 5B6, Canada.

Raman microprobe, SEM and microthermometric FI data indicate that some of the fluids responsible for transport and deposition of Ag within the veins at Cobalt were low $X(CO_2)$ saline brines. Samples from the Beaver-Temiskaming and Siscoe mines have yielded FI that can be petrographically related to the mineral paragenetic sequences for these deposits.

Growth-zoned axinites from the Beaver-Temiskaming mine containing P and PS three-phase, liquid + vapor + halite (L+ V + H) FI are cut by Ag veins. The pre-ore FI contained within the axinites show a transition from three phases (L + V + H) to two phases (L + H) in the range 190-240°C. The melting T of the salt ($L + H \rightarrow L$) vary from 230-250°C. In all cases the vapor homogenizes to the liquid prior to the melting of the salt cube. Such phase behavior is inconsistent with a boiling system.

At the Siscoe mine, rare isolated fractures contain solid inclusions of native Ag terminating in two-phase (L + V) FI, having measured freezing point depressions of 25-27°C. The depression of the H_2O-NaCl eutectic requires that some other salt component, possibly $CaCl_2$, be present to account for the inconsistencies between the observed freezing point depressions and the phase relations within the pure H_2O-NaCl binary. (Authors' abstract)

MARTEL, D.J., DEAK, J., DÖVENYI, P., HORVATH, F., O'NIONS, R.K., OXBURGH, E.R., STEGENA, L. and **STUTE, M.**, 1989, Leakage of helium from the Pannonian basin. Nature, v. 342, p. 908-912.

MARTIN, B. and **KUSHIRO, I.**, 1989, Liquid immiscibility synthesis as indicator of cooling rate of basalt (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-376.

MARTY, B., 1989, On mantle carbon flux calculated: Eos, v. 70, no. 1, p. 1.

Calculation based on ^3He, $\delta^{13}C$, and CO_2 analyses from basalts are discussed. See also Des Marais, this volume. (E.R.)

MASLENNIKOV, V.V. and **TELENKOV, O.S.**, 1988, Genetic and thermobarogeochemical peculiarities of the metal-bearing beds at the sulfide deposits of the South Urals: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 19-20 (in Russian). Authors at Inst. Mineralogy of Ural Div. of Acad. Sci. of U.S.S.R., Miass, U.S.S.R.

At the Cu sulfide deposits: Buribay, Sibay, Makan and Uzel'ya (Middle Paleozoic island arc system of the Ural paleoocean), quartz from the quartz-iron (pyrite) rocks yielded three vacuum decrepitation maxima: 80-140, 480-580, and 680-740°C; the gas consists mostly of CO_2; quartz-hematite rocks release H_2, N_2, CO and CO_2, quartz-limonite rocks—the gases listed above plus NH_3, H_2S, H_2O and SO_2. (A.K.)

MASSARE, D. and **CLOCCHIATTI, R.**, 1989, Pressure effect on homogenization temperature of fluid and melt inclusions: Data from high pressure microscope stage in the 0.1-500 MPa; 25°-1100°C range (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 65. Authors at Groupe des Sci. de la Terre, CEN/SACLAY, 91191 Gif sur Yvette, Cedex, France.

A new high P (to 700 MPa), high T (to 1400°C) microscope stage has been used to measure the P effect on Th of fluid synthetic inclusions, FI in natural hydrothermal quartz and melt inclusions in volcanic minerals. In natural and synthetic quartz, FI show a 7° to 20°C per 100 MPa P effect in the 25° to 250°C T 0.1 to 500 MPa P ranges.

Rhyolitic H_2O-rich melt inclusions, that explode before homogenization during heating experiments at 0.1 MPa, show a much greater P effect. The Th of melt inclusions trapped in sanidine in pumice decreases by up to 70°C per 100 MPa in the 560-850°C T and 0.1 to 400 MPa P ranges. (Authors' abstract)

MASSOTH, G.J., BUTTERFIELD, D.A., LUPTON, J.E., McDUFF, R.E., LILLEY, M.D. and **JONASSON, I.R.**, 1989, Submarine venting of phase-separated hydrothermal fluids at Axial Volcano, Juan de Fuca Ridge: Nature, v. 340, p. 702-705. First author at Pacific Marine Environmental Laboratory, Nat'l Oceanic and Atmospheric Administration, 7600 Sand Point Way, NE, Seattle, WA 98115-0070.

Since the discovery of high-T venting on the East Pacific Rise in 1979, it has been expected, because of the physical properties of sea water at P and T encountered during submarine hydrothermal circulation, that phase-separated fluids would discharge from ridgecrest vents. Although this notion is supported by the reported large deviations in vent-fluid chlorinity relative to that of sea water (-40%-+200%), by observations of venting at P-T conditions clearly within the two-phase region (220 bar and 420°C) and by fluid-inclusion data, unequivocal identification of phase-separated venting fluids has remained elusive. Here we report observations of chloride- and metal-depleted, gas-enriched fluids from a shallow vent field on the Juan de Fuca Ridge which confirm the expectation that phase-separated effluents are delivered to the deep ocean from some sea-floor venting systems. (Authors' abstract)

MASUDA, Michael, HALIM, Christian and **FREUND, Friedemann**, 1989, Fluid inclusion pattern in synthetic MgO crystals (abst.): Eos, v. 70, p. 1415. Authors at NASA Ames Research Center, Moffett Field, Ca 94035 and Dept. Physics, San Jose State Univ., San Jose, CA 95192.

The interaction of fluid phase components CO_2 and H_2O with minerals is of fundamental interest and still not fully understood. We have studied a large (3x3x4 cm) MgO single crystal which grew from a melt saturated with CO/CO_2 (plus H_2O) in an electric carbon arc furnace under reducing conditions and was cooled moderately fast. The rim (3-5 mm wide) is clear while the interior is turbid. The turbidity is caused by tiny bubbles (<1 μm) which decorate a complex three-dimensional network of subgrain boundaries that appear already in the clear rim and increase in density in the turbid regions. The internal surfaces are curved with respect to the perfect (100) cleavage plane, indicating that they are *not* formed by microcracking during cooling but rather by a diffusion-controlled exsolution that generated dislocations which coalesced into subgrain walls. Exsolution was apparently driven by supersaturation of the MgO with respect to gases dissolved during crystallization. Strain-strain interaction between nucleation sites has controlled the bubble precipitation. The bubbles do *not* contain now CO/CO_2 gas. Two-dimensional Monte Carlo simulations show a lowering of the total energy of the system by the progressive coalescence of the array of subgrains. (Authors' abstract)

MATHEZ, E.A. and **PINEAU, F.**, 1989, Carbon isotopic compositions of xenoliths from the Hualalai Volcano, Hawaii (abst.): Eos, v. 70, p. 510. First author at Dept. Min. Sci., Am. Museum of Natural History, New York, NY 10024, USA.

The isotopic composition of carbon has been determined in a suite of xenoliths from the 1800-1801 Kaupulehu eruption of Hualalai Volcano, Hawaii. Several lithologies are represented, including websterite, dunite, wehrlite, pyroxenite and gabbro. Composite xenoliths are also present in which contacts between lithologies are preserved. The mutual contact relations indicate that all the xenolith types originated from the same locality, probably in the mantle near the crust-mantle boundary. Most of the xenoliths represent deformed cumulates. Isotopic compositions were determined by a stepped heating procedure whereby samples were subjected to progressively higher T from 200 to 1475°C to obtain separation of the different carbonaceous phases. Grossular glass was used as a flux to fuse refractory samples.

The evolution of carbon with heating is bimodal, as observed in other studies. Carbon extracted from all samples at $T < 900°C$ is characterized by a $\delta^{13}C$ of about -26 vs PDB and is thought to be composed dominantly of graphitic and organic material, which is known to be present on virtually all microcracks. The $\delta^{13}C$ of the carbon fraction extracted at 1200°C and above from wehrlite and dunite is in the range -1.5 to -5.2, whereas that extracted from the websterites ranges from -22 to -26. This large difference can be associated with specific petrographic features unique to each lithology. In wehrlite and dunite, carbon exists mostly as CO_2 inclusions. The websterite xenoliths contain megascopic inclusion-rich zones which traverse entire thin sections and are interpreted to represent fractures annealed in the source regions. Most of the carbon in the rocks is believed to exist in these zones and to consist of carbonaceous material condensed from fluid.

The combined petrographic observations and isotopic data demonstrate that isotopic variability can be generated by multistage fractionation processes such as degassing of CO_2 from magma and condensation of CO_2-rich fluids to form graphitic compounds. Such processes may operate over regions the scales of which are determined by style of deformation and lithology. (Authors' abstract)

MATSUDA, Jun-ichi and **MATSUBARA, Kayo**, 1989, Noble gases in silica and their implication for the terrestrial "missing" Xe: Geophys. Res. Letters, v. 16, no. 1, p. 81-84.

MATSUDA, J.-I. and **NAGAO, Keisuke**, 1989, Noble gas emplacement in shock-produced diamonds: Geochim. Cosmochim. Acta, v. 53, p. 1117-1121.

MATSUO, S., 1989, Future aspects of volcanic gas studies (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-388-389.

MATTEY, D.P., **EXLEY, R.A.** and **PILLINGER, C.T.**, 1989, Isotopic composition of CO_2 and dissolved carbon species in basalt glass: Geochim. Cosmochim. Acta, v. 53, p. 2377-2386. First author at Dept. Geology, Royal Holloway and Bedford New College, Univ. London, Egham Hill, Egham, Surrey TW20 0EX, U.K.

The isotopic composition of coexisting fluid and dissolved carbon species in MORB glass have been studied using a combination of replicate stepped heating experiments, vacuum crushing and grain-size analysis. Stepped heating carbon release profiles demonstrate the presence of isotopically light carbon released by combustion below 600°C (LTC) and isotopically heavier carbon released above 600°C (HTC). Up to 95% of the LTC component, which mostly resides on the surface of the glass, can be removed by extraction in dichloromethane; combustion at 400 and 600°C ensures its complete removal prior to extraction of HTC species above 600°C. Assuming that HTC consists of fluid (i.e. CO_2 trapped within vesicles) and dissolved (i.e. carbonate ion complexes) species, limits on the net difference between the isotopic composition of coexisting fluid and dissolved carbon have been estimated from stepped heating data. The apparent magnitude of carbon isotopic fractionation between CO_2 vapour and basaltic melt is greater than 1‰ but significantly less than 4.5‰ and localized fractionation processes associated with magma degassing are associated with ΔCO_2-basalt-melt values of ≈2‰. (Authors' abstract)

McCAIG, A.M., 1989, Fluid flow through fault zones: Nature, v. 340, p. 600.

Points out that fluid flowing in fault zones may involve highly corrosive brines, in part from leaching of opened fluid inclusions. (E.R.)

McCONVILLE, P. and **REYNOLDS, J.H.**, 1989a, Cosmogenic helium and volatile-rich fluid in Sierra Leone alluvial diamonds: Geochim. Cosmochim. Acta, v. 53, p. 2365-2375. Authors at Dept. Physics, Univ. California, Berkeley, CA 94720.

Pursuant to the discovery elsewhere of cosmogenic ^{10}Be in alluvial diamond fragments from Zaire, noble gas measurements were made on two identical splits of a finely powdered, harshly acid-washed sample derived from selected (for clarity) fragments of a single alluvial diamond from Sierra Leone (sample LJA $\rightarrow$ L#4 and L#5). Essentially identical results were obtained for both splits. Isotopic ratios for Ar, Kr, and Xe were atmospheric and their elemental abundances were high relative to published data, owing to shock implantation in the crushing as verified in a supplementary experiment. No neon was detected above blank level. ^{3}He was exceptionally abundant, ^{4}He exceptionally depleted, possibly from the acid wash, and the ratio ^{3}He/^{4}He almost unprecedentedly high at an R/R_a value of 246 ± 16. The results support the hypothesis that excess ^{3}He in diamonds is cosmogenic, although a cosmic-ray exposure of 5, 35, or (impossibly) 152 Ma for cyclic gardening of the sample to a maximum depth of 0, 4.6, or 20 m, respectively, is required. Troublesome for the cosmogenic hypothesis is a sample from very deep in the Finsch mine, South Africa, found by Zadnik et al. (1987) to have an R/R_a value of 1000. Our paper includes histograms of noble gas data published prior to mid-1988 for diamonds of known provenance.

The Sierra Leone diamond studied in the supplementary experiment (sample LJE2 $\rightarrow$ L#6 and L#7) belongs to a distinct population of ^{40*}Ar-rich diamonds consisting mostly of cubic diamonds from Zaire. The latter stones, the "supplementary" Sierra Leone diamond, and a milky Brazilian diamond measured by Honda et al. (1987) all display upper mantle signatures, in common with MORB glasses and CO_2 gas wells, for ^{3}He/^{4}He, ^{40*}Ar/^{4}He, excess ^{129,134,136}Xe/^{132}Xe, and to a lesser extent in concordance, ^{136*}Xe/^{4}He. (Authors' abstract)

Includes a note added in proof discussing evidence of actual cavities (gas inclusions?) in sample LJE2. (E.R.)

McCONVILLE, P. and **REYNOLDS, J.H.**, 1989b, Cosmogenic helium and volatile-rich mantle fluid in Sierra Leone diamonds (abst.): 52nd Annual Meeting of the Meteoritical Society, Vienna Austria, July 31-August 4, 1989, Abstracts and Program, LPI Contribution 712, p. 154. Authors at Dept. Physics, Univ. California, Berkeley, CA 94720.

See previous item. (E.R.)

McGOWAN, K.I. and **SPRY, P.G.**, 1989, Basinal brine fluid source for Archean lode gold deposits, Atlantic City-South Pass district, Wyoming (abst.): Program abstracts, 101st annual meeting, Iowa Academy of Science, J. Iowa Acad. Sci., v. 96, (1), p. A23.

McKEAG, S.A. and **CRAW, D.**, 1989, Contrasting fluids in gold-bearing quartz vein systems formed progressively in a rising metamorphic belt: Otago Schist, New Zealand: Econ. Geol., v. 84, p. 22-33. First author at Vanderbilt Gold Corp., 3311 South Jones Blvd., Las Vegas NV.

Four different quartz vein systems occur within 600 km^2 in east Otago. The vein systems have formed within fault systems which crosscut regional schistosity. The Macraes system formed from almost pure water at about 3 kbars and 350°C (data from FI and arsenopyrite geothermometer). The Bonanza system formed from immiscible H_2O-CO_2-NaCl fluids at about 1000 bars. Nenthorn formed under near-surface conditions from boiling low-salinity water, with some CO_2 present. Barewood most closely resembles Macraes but is thought to have formed at slightly shallower levels. The veins formed at different times during Mesozoic-Cenozoic uplift of the Otago Schist belt. C and O isotope data and the high CO_2 content of some fluids suggest that the vein-forming fluids were metamorphogenic. A component of downward-percolating meteoric water was probably involved in shallower vein formation. Vein formation is considered to be an inevitable consequence of devolatilization of uplifting metamorphic rocks, with focusing of fluids into available structural features. Similar fluid flow has occurred within the last 1 m.y. in the northwestern extension of the Otago Schist, where Alpine fault uplift has induced Au mineralization on joint surfaces. (Authors' abstract)

McKIBBEN, M.A., 1989, Sulfur and metal transport in active geothermal systems: Applications to ore genesis and water-rock interactions (abst.): Eos, v. 70, p. 1378-1379. Author at Dept. Earth Sciences and Center for Geothermal Resources Research, Univ. California, Riverside, CA 92521.

Recent extensive commercial and scientific drilling into several active geothermal systems has provided comprehensive samples of rocks and fluids. Accompanying the availability of these samples have been the development of advanced ion probe techniques for *in situ* sulfur isotopic microanalysis and ICP mass spectrometric techniques for determining small concentrations of precious metals in solids and fluids. These new samples and techniques are allowing the development of databases on metal and sulfur transport that constrain processes of ore genesis and water-rock interaction.

Static, saline sediment-hosted geothermal systems such as the Salton Sea (CA) have long fluid residence times and very elevated base metal contents. This large system is characterized by fluid H_2S-SO_4 isotopic equilibrium, with H_2S generated by hydrothermal reduction of host-rock evaporites. Our extensive field-wide database of fluid compositions allows direct empirical determination of metal speciation and solubility in these brines, placing useful constraints on metal transport in complex saline hydrothermal fluids.

Low-salinity volcanic-hosted systems such as Valles Caldera (NM) typically exhibit fluid H_2S-SO_4 isotopic disequilibrium presumably because the host-rocks lack extensive evaporites and fluid residence times are relatively short. Evidence of past boiling in these systems is mutually preserved by FI and by sulfide minerals that show radical microscopic sulfur isotopic zonation.

In these and other active systems, Au is consistently enriched over fluid values by 10^3 to 10^6 in the mineralogically diverse wellbore scales that are deposited downhole at the flashpoint (boiling point). These relationships confirm that over broad ranges of salinity, pH and oxidation state in subcritical fluids, Au is uniformly transported as a bisulfide complex which is rapidly destabilized by loss of H_2S upon boiling. (Author's abstract)

McKIBBEN, M.A. and WILLIAMS, A.E., 1989, Metal speciation and solubility in saline hydrothermal fluids: An empirical approach based on geothermal brine data: Econ. Geol., v. 84, p. 1996-2007.

McKIBBEN, M.A., WILLIAMS, A.E. and HALL, G.E.M., 1989a, Au and PGE in Salton Sea geothermal brines (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A294.

McKIBBEN, M.A., WILLIAMS, A.E. and HALL, G.E.M., 1989b, Precious metals in the Salton Sea geothermal brines: Geothermal Resources Council, Trans., v. 13, p. 45-47. First author at Dept. Earth Sciences and Center for Geothermal Resources Research, IGPP, Univ. California, Riverside, CA 92521.

Production fluids, reservoir rock veins, well-head pipe-scales, and downhole liner scales from the Salton Sea geothermal system have been analyzed for Au and platinum group elements (PGE). Au and PGE levels in sampled production fluids are ≤ 0.3 ppb. Veins from reservoir rocks contain ≤ 5 ppb Au or PGE. In scales, PGE concentrations are ≤ 13 ppb, but Au concentrations range from 0.1 to >1000 ppm (average ≃2 ppm). The highest Au concentrations occur in downhole liner scales.

Thermodynamic calculations indicate that the reservoir brines should be transporting ≃0.2 ppb Au, in excellent agreement with the measured values in production fluids. Mass balance calculations suggest that, although the Au contents are relatively high in the scales, they represent scavenging of only ≃2% of the total Au that passes through the wellbore. A typical well produces ≃240 g (7.7 troy oz) of Au in one year; PGE transport appears to be negligible. (Authors' abstract)

McKIBBIN, Robert and ABSAR, Ahsan, 1989, A model for oxygen isotope transport in hydrothermal systems: J. Geophys. Res., v. 94, no. B6, p. 7065-7070. Authors at Geothermal Inst., Univ. Auckland, New Zealand.

As groundwater passes through porous rocks, exchange of O between the fluid and the solid matrix causes a change in the O isotope concentrations in both water and rock. If the rate at which the exchange takes place can be estimated (as a function of the isotope concentrations and T), then the time taken for a rock/water system to come to equilibrium with respect to isotope concentration might be calculated. In this paper, conservation laws are used to derive equations for the isotope transport in a porous medium; these are combined with fluid flow equations and a simple equation describing the rate of O isotope exchange between the water and the rock. The resulting set of equations is solved analytically for the zero-dimensional (lumped-parameter) model, and numerically, using typical parameters, for the one-dimensional case. (Authors' abstract)

McLAREN, A.C., FITZGERALD, J.D. and GERRETSEN, J., 1989, Dislocation nucleation and multiplication in synthetic quartz: Relevance to water weakening: Phys. Chem. Minerals, v. 16, p. 465-482.

McLIMANS, R.K. and VIDETICH, P.E., 1989, Diagenesis and burial history of Great Oolite Limestone, southern England: Am. Assoc. Petrol. Geol. Bull., v. 73, no. 10, p. 1195-1205. First author at Conoco, Inc., Ponca City, OK 74603.

Oil is produced from the Middle Jurassic Great Oolite Limestone in the western Wealden basin, England. Additional production was discovered (150 STBOPD, 42° API) in 1986 at the Conoco 1 Storrington well. The Storrington discovery is of note because the porosity in reservoir grainstones and packstones is largely primary and averages 19.4%, the highest value yet found for the Great Oolite. Secondary porosity is of little significance. For all wells studied, porosity in Great Oolite grainstones and packstones ranges between 3 and 20%, and there is no relation between porosity and lithology. Locally, porosity may be largely occluded by coarse calcite spar, which FI studies show precipitated in the deep-burial environment. Exploration in the Great Oolite, therefore, must seek diagenetic fairways wherein primary porosity has been preserved.

Limestones in the producing interval of the Great Oolite at 1 Storrington contain zoned syntaxial cements, are generally high in Mg content, and have stable isotope compositions that indicate the involvement of marine waters (relatively heavy $\delta^{18}O$). Our interpretation is that the limestones were stabilized early in a mixing zone between freshwater and marine phreatic environments.

Coarse calcite spar in the Great Oolite contains aqueous and oil I. The results of geothermometry studies show that the precipitation of calcite cements occurred at depth, near maximum burial, and at certain locations, was synchronous with oil migration. Inversion of the basin was a later event. The construction of burial history diagrams that incorporate FI and maturation data shows that oil migration was during the Late Cretaceous. A distribution pattern for oil I in the Great Oolite indicates migration was mainly in the western part of the basin and initially into pre-Late Cretaceous traps. (Authors' abstract)

McMILLAN, P.F., 1989, Raman spectroscopy in mineralogy and geochemistry: Ann. Rev. Earth Planet. Sci., v. 17, p. 255-284.

Topics discussed include glass-melt structure, volatiles in melts, speciation in aqueous fluids, FI, and phase transitions in solids. (E.R.)

McMURTRY, G.M., STOFFERS, P. and CHEMINEE, J-L, 1989, Comparative geochemistry of hotspot hydrothermal systems on Loihi, Teahitia and Macdonald seamounts (abst.): Eos, v. 70, p. 1397-1398.

McPHAIL, D.C. and CRERAR, D.A., 1989a, The stability of aqueous iron chloride complexes from hydrothermal solubility experiments (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A102-103.

McPHAIL, D.C. and CRERAR, D.A., 1989b, Redox and acidity control in Fe-bearing hydrothermal solubility experiments (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-32.

MEEN, J.K., EGGLER, E.H. and AYERS, J.C., 1989, Experimental evidence for very low solubility of rare-earth elements in CO_2-rich fluids at mantle conditions: Nature, v. 340, p. 301-303. First author at Dept. Geosciences, The Pennsylvania State Univ., University Park, PA 16802.

Chemical compositions of mantle-derived magmas and mantle xenoliths suggest that some regions of the mantle were enriched in basaltic components (CaO, FeO, Al_2O_3 and alkalis), large-ion lithophile elements, or both before melting or disruption and entrainment. Some peridotite xenoliths that are depleted in basaltic components contain clinopyroxenes with chondrite-normalized La/Yb ratios of >30 and La contents of 100-times chondritic. Other xenoliths with similar major-element chemistry contain clinopyroxenes with La_N/Yb_N = 0.1-1 and [La] = 1 - 10-times chondritic. Enrichment in light rare-earth elements without concomitant increase in basaltic components has been called "cryptic metasomatism." Here we present the results of experiments at high T and P, which show that CO_2-rich fluids, the postulated agents of cryptic metasomatism, dissolve only minor amounts of rare-earth elements, and cannot therefore be responsible for such enrichments. (Authors' abstract)

MEGAW, P.K.M., 1989, Sulfur isotope geochemistry of the Santa Eulalia mining district, Chihuahua, Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A150. Author at Dept. Geosciences, Univ. Arizona, Tucson, AZ 85721.

Mineralization at Santa Eulalia occurs in the West Camp (WC) as massive sulfide ores (MS) and in the East Camp (EC) as sulfide-rich skarn (SK), hosted in a thick section of limestone underlain by pyritic black shale and anhydrite. The sulfides in both areas consist of galena (gn), sphalerite (sp), and pyrrhotite (po) with local pyrite (py). Fluid inclusions in MS and SK yielded uncorrected Th of 250-450°C from both hypersaline and dilute fluids.

Sulfur isotope analyses (presented in permil relative to CDT) were performed on four sedimentary rocks and 79 ore sulfide samples with the following results: black shale pyrite (-28); anhydrite (+15.6); EC-SK (-13.5 to +4.5); WC-MS (bimodal: -17.5 to -13 and -13 to -6.5). Sp and po are lighter than in 18 of 20 gn-sp and gn-po pairs. Eight pairs yielded calculated T of 250-475°C. There is no systematic isotopic difference between po-bearing and py-bearing mineralization, nor is there a correlation between sulfur isotopes and fluid inclusion T, salinity, ore type, or metals ratios. Sulfur isotopic zoning is crude in the WC and absent in the EC.

The predominance of po and T of 250-450°C indicates mineralization occurred under reduced conditions, at low pH, in the H_2S-dominant field. Coupled with the sulfur isotope ranges of 20‰ and isotopic disequilibrium, the data indicate: multiple S sources; relatively S-poor fluids; and that the fluids must have acquired their S outside the site of mineralization.

Mass balance calculations indicate that incorporation of varying proportions of S from anhydrite and black shale pyrite to a metals-rich saline fluid can account for the patterns and variations seen throughout the district. (Author's abstract)

MELLING, D.R., TAYLOR, R.P., WATKINSON, D.H. and WU, Xin, 1989, Grant 323: Lithogeochemical, isotope and fluid inclusion studies of hydrothermal alteration and breccia veins from the Cameron Lake gold deposit, northwestern Ontario: Ontario Geol. Surv. Misc. Paper 143, p. 94-103. First author at Dept. Earth Sciences and Ottawa-Carleton Geoscience Centre, Carleton Univ., Ottawa, Canada.

The Cameron Lake deposit is an Archean vein-type deposit which occurs in deformed basaltic rocks of the Cameron Lake shear zone. The introduction of Au into the shear zone, via a fluid of external derivation, was accompanied by the addition of large amounts of CO_2, K, Rb, Ba, Ca, Sr, Ag and S. Lithogeochemical and statistical analysis of samples of potentially ore-grade material (Au = 2.25 to 7.00 g/t) from the deposit demonstrates that, of these elements, only S, Ag, Sr and Ba have a positive correlation with Au, and that CO_2, K, Rb and Ca are non-correlated with Au. These data corroborate the results of textural studies which established that, of the most common alteration minerals ankerite, sericite and pyrite, only pyrite has a close spatial relationship with Au.

Fluid inclusion petrography indicates the ubiquitous presence of CO_2-H_2O bearing inclusions, some of which contain dms, in quartz from the breccia veins and other auriferous structures. Heating-freezing experiments on these inclusions demonstrate the presence of a moderately high T (>230°C), low salinity (<3 wt % eq. NaCl), low density (0.73 g/cm^3) fluid in the shear zone during vein formation and hydrothermal alteration. Isotopic analysis of vein and alteration minerals suggests that this fluid carried isotopically light carbon (δ^{13}C ≃ -5‰), and had an initial ^{87}Sr/^{86}Sr isotopic ratio in the range 0.7012 to 0.7016. (Authors' abstract)

MERNAGH, T.P. and **WILDE, A.R.**, 1989, The use of the laser Raman microprobe for the determination of salinity in fluid inclusions: Geochimica Cosmochim. Acta, v. 3, p. 765-771. First author at Bureau Min. Resources, Canberra, ACT 2601, Australia.

The O-H stretching region (2800-3800 cm^{-1}) in Raman spectra of aqueous solutions is sensitive to changes in the salt concentration. This permits determination of the salinity in the aqueous phase of FI (at room T) by calculating skewing parameters from Raman microprobe spectra. The technique does not require detailed knowledge of the fluid composition and can be applied to most chloride solutions which commonly occur in FI. Studies of synthetic FI from the NaCl-H$_2$O system show that salinities up to halite saturation may be determined to within ±2 wt %.

Well-characterized FI from the unconformity-related U deposits of Nabarlek and Koongarra, Northern Territory, Australia, were studied with the laser Raman microprobe. The salinities determined from the Raman spectra are comparable to those obtained using standard microthermometric techniques. The Raman microprobe technique has the advantage of not requiring analogy to binary salt-water phase diagrams which cannot adequately model the complex brines in these inclusions. Variations in the concentration of salt hydrates, observed in Raman spectra of frozen inclusions, validated the salinities derived from the Raman skewing parameters obtained at room T. The Raman analyses confirm previous microthermometric evidence for trapping of discrete high and low salinity fluids. (Authors' abstract)

METRICH, N. and **CLOCCHIATTI, R.**, 1989, Melt inclusion investigation of the volatile behaviour in historic alkali basaltic magmas of Etna: Bull. Volcanol., v. 51, p. 185-198. Authors at Laboratoire Pierre Sue, Groupe des Sciences de la Terre, Centre d'Etudes Nucléaires, Saclay, F-91191 Gif-sur-Yvette Cedex, France.

Crystallization paths of basaltic (1763 eruption) and hawaiitic (1865 and 1329 eruptions) scoria from Etna were deduced from mineralogy and melt inclusion chemistry. The volatile behaviour was investigated through the study of melt inclusions trapped in the phenocrysts and those of the whole rocks and the matrix glasses. The results from the 1763 eruption point to the early crystallization of olivine Fo 81.7 from a water-rich alkaline basalt, with high Cl (1750-2000 ppm) and S (2100-2400 ppm) concentrations. The hawaiitic melt inclusions trapped in olivine Fo 74, salite and plagioclase are characterized by a decrease in Cl/K$_2$O and S/K$_2$O ratios. In each investigated system there is good correlation between K$_2$O and P$_2$O$_5$. In the whole rocks, Cl ranges from 980 to 1680 ppm, from basaltic to hawaiitic lavas, whereas S (110-136 ppm) remains low. Cl and S behaviour in the 1763 magma suggests an early degassing stage of Cl and S, with CO$_2$ and a water-rich gaseous phase for a P close to 100 MPa, consistent with a permanent outgassing at the summit craters of Etna. During the eruption, the sulphur remaining in the hawaiitic liquid is lost, and the degassing of chlorine is limited. Such a degassing model can be extended to the 1865 and 1329 A.D. eruptions. (Authors' abstract)

The analyses were performed using a 5-10 μm diameter 1.45 MeV deuteron beam at 500 pA. (E.R.)

METRICH, N., MOSBAH, M., TROCELLIER, P. and **CLOCCHIATTI, R.**, 1986, Nuclear microprobe analysis of carbon within glass inclusions and volcanic materials, *in* J.D. Brown and R.H. Packwood (eds.), 11th Int'l Cong. on X-ray Optics and Microanalysis, London, Canada, 4-8 Aug. 1986: Proceedings, p. 169-174. Authors at Centre d'Etudes Nucleaires de Saclay, France.

Elements such as C, H, N, S, Cl represent the major components of the volatile phase dissolved in magmas. These dissolved gases could be preserved within glasses (or silicate melt inclusions) trapped during crystal growth.

Microanalysis possibilities have been explored to determine light element concentrations within glasses (melt inclusions and basaltic glass fragments) and volcanic phenocrysts. In the first step, C was examined. The study of different spectral interferences lead to calculated detection limits of 40 μg/g for basaltic glasses and 50 μg/g for olivine crystals. The C contents of all investigated specimens range from 40 μg/g (the detection limit) to 6800 μg/g. Heterogeneities were revealed within glass inclusions. Measurements show obvious concentration profiles in basaltic glass samples. Our results agree with previous published data and are reliable. Accuracy of measurements is about 20%. (Authors' abstract)

The analyses were performed using a 5-10 µm diameter 1.45 MeV deuteron beam at 500 pA. (E.R.)

METRICH, N. and **SIGURDSSON, H.**, 1989, Role of CO_2 as carrer [carrier] gas in degassing of sulfur during the 1783 Lakagigar eruption (Iceland) (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 188. First author at Laboratoire P. Sue, CEN-Saclay, 91191, Gif-sur-Yvette, France.

12.3 km [km^3?] of basaltic magma were produced during the 50-day Lakagigar eruption, which may have been derived from a high-level reservoir of the Grimsvotn central volcano. Whole-rock composition is Fe-Ti basalt (Mg# 0.45). However, melt inclusions trapped in anorthitic plagioclase and Fo_{86} to Fo_{75} olivines show a large range of compositions, from rare olivine-tholeiite (Mg# 0.64, K_2O 0.10 wt %) to Fe-Ti basalt (Mg# 0.59-0.42; K_2O 0.3-0.4 wt %). Most matrix glasses are Fe-Ti basalts, with Mg# from 0.47 to 0.37. The most differentiated liquids (Mg# 0.34) are rich in TiO_2 and FeO and are trapped as rare melt inclusions in clinopyroxenes. The observed range of chemical compositions indicates that the magma chamber was vertically zoned before eruption, with Fe-Ti basalt as dominant type and with highly evolved Fe-Ti rich basalt confined at the top. Occurrence of olivine-tholeiite magma is consistent with periodic refilling of the magmatic system. Major element variations in Fe-Ti basalt are also considered as the result of both magma-mixing and fractional crystallization processes.

Cl contents increases from 50 ± 50 ppm in primitive tholeiite up to 230 ± 100 ppm in Fe-Ti basalts, without clear evidence of degassing. Melt inclusions show that sulfur varies from 1000 ± 200 ppm to 2020 ± 100 ppm, for Mg# between 0.63 and 0.41. Sulfur degassing correlates both with vesicularity and magma composition. Thus in matrix glasses sulfur decreases from 1490 ± 160 ppm to 500 ± 150 ppm, as Mg# decreases (0.47 to 0.37) and vesicularity of the magma (~1 to 65 vol %) strongly increases. These results imply that at least 75% of the initial sulfur content has been lost during the eruption. Low sulfur content of matrix glasses can be regarded as the effect of efficient degassing in relation to the vesicularity of the magma. The high vesicularity of some tephra indicates the presence of a major volatile phase. There is no evidence for high H_2O content in this magma, but the most probably major volatile phase is CO_2.

Our model is consistent with the hypothesis of CO_2 degassing of primitive tholeiite magma at depth, inducing a quasi-permanent CO_2 flux to the shallow-level magmatic reservoir, and accumulation of a CO_2-rich free volatile phase in the upper part of the system. Vertical gradients in CO_2-induced vesicularity and major element magma composition were established in the reservoir. During magma withdrawal from the reservoir and eruption, sulfur degassing was controlled by inherent CO_2-induced vesicularity of the magma. These results have important implications for degassing of basic and CO_2-rich magmas during volcanic eruptions, as they indicate that the efficiency of sulfur degassing is largely controlled by the vesicularity and abundance of a free CO_2-rich volatile phase. (Authors' abstract)

MEUNIER, J.D., 1989a, Assessment of low-temperature fluid inclusions in calcite using microthermometry: Econ. Geol., v. 84, p. 167-170. Author at Centre de Recherches sur la Géol. de l'Uranium & Groupement Sci. CNRS-CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

The results demonstrate that the nonrenucleation of the vapor phase in relatively low-T and low-salinity, two-phase aqueous FI may change the estimation of Th and limit the measurements of Tm. Th will be overestimated if FI were homogenized during a subsequent thermal event, at a lower P after trapping. If the persistence of the nonrenucleation of the bubble during experiments in a laboratory at atmospheric P is applied to geological time, then single-phase inclusions, frequently observed in diagenetic minerals, must be carefully reexamined. (From author's conclusions)

MEUNIER, J.D., 1989b, Diagenesis and ore deposition in sandstone-hosted uranium-vanadium deposits in the Colorado Plateau; evidence from fluid inclusions, *in* E. Muller-Kahle, ed., Uranium resources and geology of North America: Proc. Technical Committee Meeting on Uranium Resources and Geology of North America, Saskatoon, SK, Sept. 1-3, 1987, Int'l Atomic Energy Agency, Div. Nucl. Fuel cycle, Vienna, Austria, IAEA-Tecdoc, p. 227-238.

MEUNIER, J.D. and **BREIT, G.N.**, 1989, Fluid inclusions in calcite associated with Cu, U and V deposits in sandstones from the Colorado Plateau (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 45. First author at CREGU and GS C.N.R.S.-CREGU, BP 23, 54501 Vandoeuvre les Nancy, France.

FI in calcite were used to estimate T and composition of the paleofluids experienced by the Cu, U and V-bearing sandstones of the Colorado Plateau (U.S.A.). P, S and PS FI were identified. Firstly, the significance of microthermometric data was evaluated. Metastability, leakage and stretching phenomena, commonly encountered during microthermometric studies of diagenetic minerals, have been recognized in calcite related to the Lisbon Valley fault. The results demonstrate that the non-renucleation of the vapor phase in relatively low-T and low-salinity FI, may change the estimation of Th and limit the measurements of Tm.

Calcite in faults near Cu deposits in Lisbon Valley, Utah, and calcite replacing wood in sandstones hosting U-V deposits within the adjacent Slick-Rock district, Colorado, show similar results. Th range from 70 to 100°C and Tm range from 0 to -10°C corresponding to salinities of 0 to 14 wt. % Nacl. Typically S FI are characterized by a 90-95°C Th range and high salinities while P ones exhibit variable Th and Tm. These results indicate changes of fluid composition with time as the calcite grew. Calcite from the Dolores zone of faults cutting the Morrison formation, exhibits distinct FI data. The fluids are dilute with Th = 50°C.

Calcite in the Lisbon Valley fault and in the Slick Rock district have oxygen isotope values ($\delta^{18}O$) between +16 and +18‰ (SMOW). Aqueous solutions which precipitated the calcite are characterized by $\delta^{18}O$ of -4 to -1‰ (SMOW) consistent with basinal brines. The brines were responsible for Cu mineralization during late diagenesis and probably altered the U-V deposits. In contrast, calcite from the Dolores zone of faults have $\delta^{18}O$ values ranging from +7.5 to +11‰ (SMOW). The calcite thus formed from water of -15‰, which is the composition of modern meteoric groundwater near the study area. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p. 266-267. (E.R.)

MEYER, A.J., LANDAIS, P., BROSSE, E., PAGEL, M., CARISEY, J.C. and **KREWDL, D.**, 1989, Thermal history of the Permian formations from the Breccia Pipes area (Grand Canyon region, Arizona): Geol. Rundsch. 1989, v. 78(1), p. 427-438. Authors at Cent. Rech. Geol. Uranium, 54501 Vandoeuvre-les-Nancy, France.

The thermal history of the Permian sedimentary formations in the Breccia Pipes area of the Colorado Plateau was assessed using various methods. Burial reconstruction indicates max. T of 100-140° for a 30°/km geothermal gradient. A T of 140 ± 5° integrated over 10-50 Myr is deduced from fission-track anal. This T range is consistent with trapping T obtained by FI study (75-140°). Fission-track and burial hypotheses were incorporated in a kinetic model for org. matter maturation, with the max. T calcd. as 445 and 421°, resp. A comparison with org. geochem. data from the Permian Toroweap Formation is carried out and demonstrates that the two above-mentioned hypotheses constitute a thermal framework for the org. matter evolution. Main conclusions referring to beginning of oil window and regional uplift ages (Laramide orogeny) as well as max. T ranges are deduced. (Ca 113:44000f)

MICHAEL, P.J. and **SCHLLING, J-G.**, 1989, Chlorine in mid-ocean ridge magmas: Evidence for assimilation of sea-water-influenced components: Geochim. Cosmochim. Acta, v. 53, p. 3131-3143. First author at Dept. Geosciences, Univ. Tulsa, 600 S. College Ave., Tulsa, OK 74104.

Suites of depleted MORB glasses from the fast-spreading Pacific-Nazca Ridge at 28°S and 32°S and the slow-spreading eastern boundary of the Juan Fernandez microplate were analyzed for chlorine by electron microprobe. The Cl concentrations in FeTi basalts exceed by a factor of 5 to 10 the amounts that can be generated by fractional crystallization of the primitive magmas. Assimilation of hydrothermally altered wall rocks of the magma chamber most likely provides the extra Cl and H_2O. Selective melting or breakdown of amphibole and incorporation of Cl-rich brine contained in the wall rocks may be important processes. Bulk assimilation is less likely because the Cl content of altered crust is too low to generate the excess Cl unless unrealistically large amounts of assimilation are invoked. A magmatic source for the additional Cl and H_2O cannot be ruled out on geochemical grounds but is physically unrealistic because it requires that large volumes of magma have crystallized and exsolved a Cl-rich vapor phase that has somehow migrated to a small magma chamber.

The existence of high-Cl magmas implies that some of the Cl-rich mineralization observed in deep crustal sections and ophiolites could be due to exsolved magmatic volatiles. The assimilation of hydrothermally altered material could influence the concentration and isotopic ratios of other elements which have low abundances in MORB relative to seawater. (From authors' abstract by E.R.)

MICHARD, Annie, 1989, Rare earth element systematics in hydrothermal fluids: Geochimica Cosmochim. Acta, v. 53, p. 745-750. Author at CRPG and Ecole Nationale Supérieure Géol. de Nancy, B.P. 20, 54501 Vandoeuvre-lOs-Nancy Cedex, France.

Rare earth element concentrations have been measured in hydrothermal solutions from geothermal fields in Italy, Dominica, Valles Caldera, Salton Sea and the Mid-Atlantic Ridge. The measured abundances show that hydrothermal activity is not expected to affect the REE balance of either continental or oceanic rocks. The REE enrichment of the solutions increases when the pH decreases. High-T solutions (>230°C) percolating through different rock types may show similar REE patterns. (Author's abstract)

MILES, D.L. (ed.), 1989, Water-Rock Interaction WRI-6, Rotterdam, Balkema.

Contains many pertinent papers, abstracted in this volume. (E.R.)

MILLEDGE, H.J., MENDELSSOHN, M.J., BOYD, S.R., PILLINGER, C.T. and **SEAL, M.**, 1989, Infrared topography and carbon and nitrogen isotope distribution in natural and synthetic diamonds in relation to mantle processes (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 55-60.

MILLER, M.F., SHEPHERD, T.J., YUCHENG, L. and **HALLS, C.**, 1989, The source and significance of carbon isotopes in FI from mineralized areas of SW England and S China (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 66. First author at British Geol. Survey (N.E.R.C.), Geochem. & Hydrogeol. Div., 64 Gray's Inn Road, London WC1X 8NG.

Previous FI studies of mineralization associated with the eastern sector of the Cornubian batholith, SW England, have recognized the association of CO_2-rich (>0.5 mole %) hydrothermal fluids with endo- and exogranitic W deposits. In the present investigation, abundances and C isotopes of CO_2 from FI in quartz veins from Hercynian granite-hosted W ± Sn mineralization, determined by a stepped thermal decrepitation extraction technique, are presented and compared with data obtained for other granite-related Sn-W deposits, with particular reference to occurrences associated with the Yanshanian granites of S China.

The C isotope $\delta^{13}C$ results for the SW England samples range from -7 to -9.8‰ (PDB) for the extracted CO_2. Whilst not unambiguous, the most likely assignment of C sources from the stable isotope data is consistent with a predominantly deep-seated origin (mantle or lower crustal), with a minor contribution arising from interaction with the local low-grade, regionally metamorphosed Devonian-Carboniferous volcanic-sedimentary envelope. The indigenous total C content of the latter is low; generally <250 ppm. It is postulated that the CO_2 is thus a primary feature associated with the magmatic hydrothermal component (the presence of which is confirmed by combined H and O stable isotope measurements), whilst the occurrence of the minor volatile components CH_4 and N_2 in the fluid is indicative of the release of organic material from the sediments. Further support of this view is provided by the finding that $\delta^{13}C$ values of CO_2 also present in hydrothermal fluids at an earlier stage of evolution (pneumatolytic facies from the St. Austell granite, representative of the transition from pegmatite lodes to pneumatolytic-hydrothermal vein systems) are comparable (-8.8 to -11.7‰), even though the concentration of this component is low (0.5 to 4 ppm C, whole rock, corresponding to between 0.06 and 0.3 mole % in the fluid). Evidence for a magmatic component to the evolving hydrothermal system is provided by H isotope data for the fluid.

FI compositions of quartz vein samples from Jiangxi and Hunan provinces of S China, by contrast, exhibit CO_2 as the only significant non-aqueous volatile, with $\delta^{13}C$ values ranging from 0-3.0 to -6.8‰; these data are also in accordance with a deep-seated origin for the C, possibly exhibiting slight enrichment of ^{12}C as a result of fluid interaction with carbonate minerals of marine origin. (Authors' abstract)

MILLER, T.H., ZOLLER, W.H. and JANECKY, D.R., 1989, Elemental and molecular composition of volatile species in magmatic vapors (abst.): Eos, v. 70, p. 1410.

MIRONOV, A.G., KONNIKOV, E.G. and EPEL'BAUM, M.B., 1989, Studies of dynamics of melting of water-saturated basalt with use of tritium: Doklady Akad. Nauk SSSR, v. 309, no. 6, p. 1146-1449 (in Russian). First author at Geol. Inst. Buryatian Sci. Center, Ulan-Ude, U.S.S.R.

The effect of non-uniform H_2O distribution at the border of melting basalt was evidenced in this paper. Pertinent also to establishing the heating time during homogenization runs of basalt melt inclusions. (A.K.)

MIZUTANI, Yoshihiko, TOKIWA, Minoru and SATAKE, Hiroshi, 1989, Hydrogen and carbon isotopic compositions of methane in N_2- and CO_2-rich gases from Central Japan: Geochem. J., v. 23, p. 65-73. Authors at Dept. Earth Sciences, Toyama Univ., Gofuku, Toyama 930, Japan.

N_2- and CO_2-rich bubble gases collected from five springs and four wells in Paleozoic metamorphic rock and Cretaceous granite areas of Central Japan contain up to 22.9% methane. δD and $\delta^{13}C$ values are between -100 and -180‰ and -24 and -51‰, respectively, for the methane. A linear correlation between δD and $\delta^{13}C$ values observed is almost identical with that for the TT(m) type thermogenic methane. The methane in the bubble gases is likely to be originated by thermal decomposition of organic matter in deep-seated metasedimentary rocks. The contribution of volcanic, magmatic and mantle-derived methanes to the bubble gases is probably insignificant, whereas $^3He/^4He$ values given by previous works indicate the presence of gas components derived from deep-seated sources, such as the magma, lower crust and mantle, in the gases. (Authors' abstract)

MOINE, Bernard, FORTUNE, J.P., MOREAU, Philippe and VIGUIER, Francis, 1989a, Comparative mineralogy, geochemistry, and conditions of formation of two metasomatic talc and chlorite deposits: Trimouns (Pyrenees, France) and Rabenwald (Eastern Alps, Austria): Econ. Geol., v. 84, p. 1398-1416. First author at Laboratoire de Minéralogie, U.A. 67 du Centre National de la Recherche Scientifique, Université Paul Sabatier, 39 Allées Jules Guesde, F.31000 Toulouse, France.

The Trimouns (French Pyrenees) and Rabenwald (Austrian Alps) talc and chlorite deposits occur within Paleozoic metamorphic series (Hercynian metamorphism) and are primarily of sedimentary origin. They were produced by metasomatism in zones of intense deformation (thrust planes, surfaces of tectonic slicing) of late Hercynian (Trimouns) and Alpine (Rabenwald) age. The mineral assemblages and the mineral chemical composition point to a contrast in crystallization conditions: ~T = 400°C and P = 1 kbar at Trimouns; T = 500° to 550°C and P = 8 to 9 kbars at Rabenwald.

Talc-rich ores originate from carbonates (dolomite, magnesite), whereas Mg chlorite-dominant ores result from the alteration of the silicoaluminous rocks (mica schists, gneisses, and associated felsic igneous rocks). In the latter case, large quantities of Mg are added while Na, K, and Ca are entirely leached, as documented by extensive data on the chemical composition of the rocks. Quartz is totally absent from the ores due to alteration into talc and by dissolution. At Trimouns (low P) Al is a quasi-inert component, whereas a relatively high mobility is evidenced at Rabenwald (high P).

A fluid inclusion study (microthermometry and leachate analyses) of quartz from recrystallized pods in zones adjacent to the talc-chlorite ores shows very typical solutions with similar compositions in both deposits—high salinity with halite often present at room T, relatively high Ca and Mg concentrations, and low CO_2 content—leading to the alteration of the carbonates at relatively low T. In other respects, the respective isochores confirm the P contrast between the two localities.

All these data provide constraints regarding the physical and chemical conditions of the hydrothermal alteration. It is noticeable that the high salinity of the solutions seems to be an important factor in explaining the crystallization of talc and the absence of tremolite. (Authors' abstract)

MOINE, Bernard, FORTUNE, J.P., MOREAU, Philippe and VIGUIER, Francis, 1989b, Conditions of formation of the Trimouns (Pyrenees, France) and Rabenwald (Eastern Alps, Austria) metasomatic talc and chlorite deposits (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 12. First author at Laboratoire de Minéralogie, Univ. Paul Sabatier, 39 Allées Jules Guesde, 31000 Toulouse, France.

[These two] talc and chlorite deposits occur within Paleozoic metamorphic series. They were produced by metasomatism in zones of intense deformation of Hercynian (Trimouns) and Alpine (Rabenwald) age. The crystallization conditions were approximately: $T = 400°C$ and $P = 1$ kb at Trimouns; $T = 500\text{-}550°C$ and $P = 8\text{-}9$ kb at Rabenwald, where the talc-phengite assemblage is characteristic.

Talc-rich ores originate from carbonates (dolomite, magnesite) whereas Mg-chlorite dominant ores result from the alteration of the silico-aluminous rocks (mica schists, gneisses and associated felsic igneous rocks). In the latter case, large quantities of Mg are added while Na, K and Ca are entirely leached, as documented by extensive data on the chemical composition of the rocks. Quartz is totally absent from the ores due to alteration into talc and by dissolution.

A fluid inclusion study (microthermometry and leachate analyses) of quartz from recrystallized pods in zones adjacent to the talc-chlorite ores show very typical solutions with similar compositions in both deposits: high salinity with halite often present at room T; relatively high Ca and Mg concentrations; low CO_2-content, this leading to the alteration of the carbonates at relatively low T. The high salinity of the solutions seems to be an important factor in explaining the crystallization of talc and the absence of tremolite.

Using a simple model of metasomatic alteration, a water/rock ratio of about 1000 is calculated for the overall alteration of dolomite into talc of Trimouns. (Authors' abstract)

MOKHOSOEV, M.V., SHURDUMOV, G.K., KHAKULOV, Z.L. and **KOSHKAROV, Zh.A.**, 1989, Algorithm of the theoretical-experimental study of the phase complex of three-component systems with peritectics: Doklady Akad. Nauk SSSR, v. 305, no. 2, p. 376-379 (in Russian). Authors at Kabardine-Balkarskiy State Univ., Nal'chik, USSR.

Besides the title problem, the paper presents the system Na_2MoO_4-NaF-Na_2CO_3 at T 550-990°C, whose join NaF-Na_2CO_3 may be pertinent to inclusions of carbonatite melts. (A.K.)

MOLLING, P.A. and **SVERJENSKY, D.A.**, 1989, Thermodynamic analysis of ore fluids at the Questa Mo-porphyry deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A151.

MOLNAR, F., 1989a, Micro-evolution of paleohydrothermal systems based on fluid inclusion studies of quartz crystals that exhibit periodic growth (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 67. Author at Mineral. Dept., Eotvos L. Univ., 4/A Muzeum Krt., Budapest H-1088, Hungary.

Along the outcrops of the ore veins of the Paleogene-Neogene polymetallic (±Au,Ag) ore deposits (Matra Mts., and Tokaj Mts., NE Hungary), occurrences of idiomorphic quartz crystals are widespread. These grew freely within cavities in the host rocks (andesite and rhyolite tuff) and differ morphologically from the vein quartz aggregates. The crystals show periodic growth, and occurrences of scepter quartz and its syntaxial overgrowth are very characteristic. The morphological differences refer to variations in the paleohydrothermal system during crystal growth.

The form and position of the larger FI suggest skeletal growth of the host quartz. Crystals with a similar morphology in the various ore deposits grew at ~100-250°C. The salinity of the FI varies between 0.5 and 7 wt % NaCl eq., and the solution compositions are mixed, alkaline-chloride-(bi)carbonate-sulphate type. Boiling is considered to have taken place, between 5 and 50 bars. The gas inclusions contain not only water vapor, but CO_2 and CH_4.

The most important changes which occurred during the growth of these crystals were cooling or thermal pulsing of the fluids, and the mixing of the chloride and non-chloride type solutions. FI data of the quartz crystals from various parts of the ore deposit suggest either that the crystals did not grow contemporaneously or that the local evolution of the hydrothermal system varied from place to place. The quartz crystals studied were developed in the apical or marginal zone of the paleohydrothermal system. (Author's abstract)

MOLNAR, F., 1989b, Secondary fluid inclusions in magmatic quartz and their application to the reconstruction of paleohydrothermal activity Au-Hg mineralization, Tokaj Mts., N.E. Hungary (abst.): ECROFI, European Current

Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 68. Author at Mineral. Dept., Eotvos L. Univ., 4/A Muzeum Krt., Budapest H-1088, Hungary.

The ore occurrences are related to Middle-Upper Miocene andesitic-rhyolitic volcanic activity in the area of Tokaj Mountains. The studied Au-pyrite and cinnabar deposits are situated along the SE margins of the mountains. The host rocks (rhyolite tuff and pyroxene andesite) of the precious metal-bearing ore occurrence have undergone strong K-metasomatism, while wall rock alteration associated with the Hg mineralization exhibits a zonal distribution of silicification, argillitization, alunitization, baritization as well as weak K-metasomatism in the host rhyolite tuffs.

Hydrothermal minerals, suitable for FI studies (quartz crystals) are very rare in the area of the Au-occurrence. However, the hydrothermal fluids were trapped as S inclusions in magmatic quartz crystals in rhyolite tuff. These S FI occur in space occupied by volcanic glass inclusions, or along healed fractures (Th: 210-300°C; salinity: 4-7 wt % NaCl eq.). The evolution of paleohydrothermal activity was reconstructed using these S FI in magmatic quartz, where non-opaque hydrothermal minerals are absent.

According to the studies of the hydrothermal inclusions of the magmatic quartz, hydrothermal quartz and barite from the Hg-mineralization, it was determined that cooler and less saline fluids generated the cinnabar mineralization (Th: 120-240°C; salinity: 0-3.5 wt % NaCl eq.). The ore assemblage is thought to have developed in the shallower boiling zone of the hydrothermal system. Under the cinnabaric "siliceous cap" there is probably an ore mineralization which is similar to the Au-bearing occurrences in the studied area. (Author's abstract)

MONNIN, Christophe, 1989, An ion interaction model for the volumetric properties of natural waters: Density of the solution and partial molal volumes of electrolytes to high concentrations at 25°C: Geochim. Cosmochim. Acta, v. 53, p. 1177-1188.

MONTANA, Art and **BOETTCHER, Scott**, 1989, Noble gases in silicate liquids: Ar, Xe, and Ar-Xe mixes (abst.): Eos, v. 70, p. 1402.

MONTANA, Art and **BREARLEY, Mark**, 1989, An appraisal of the stability of phlogopite in the crust and in the mantle: Am. Mineral., v. 74, p. 1-4. First author at Inst. Geophys. and Planet. Physics and Dept. Earth and Planet. Sci., Univ. California, Los Angeles, Los Angeles, CA 90024-1567, USA.

Experimental and theoretical investigations of phlogopite at high P serve as a guide to the role of water in the melting of crustal and mantle rocks. We propose that the geometrical arrangement of phase relationships of phlogopite-bearing olivine-normative assemblages characteristic of the upper mantle is similar to that of crustal, quartz-normative assemblages. Despite differences in interpretation of some experimental data on the stability of phlogopite, nearly all of the results—including some new ones that are presented here—are consistent with these proposed phase relationships, which provide a sound basis for future research. (Authors' abstract)

MOON, K.J., 1983, The genesis of the Sangdong tungsten deposit, the Republic of Korea: Ph.D. dissertation, Univ. Tasmania, Hobart, 372 pp.

Includes extensive studies of the many types of inclusions found at Sangdong, in pyroxene, garnet, quartz, scheelite, fluorite, apatite, vesuvianite, amphibole and biotite (only two inclusions). Some CO_2 was found and some evidence of boiling. Some liquid immiscibility of unknown nature was recognized at high T (~500°C) in one inclusion in vesuvianite. Dms include various isotopic, anisotropic and opaque phases, possibly including hematite, magnetite, calcite, halite, sylvite, and iron chlorides. The thermometric data are plotted and contoured in terms of depth and position in the mine, type of vein, skarn or mineral assemblage, paragenetic sequence, etc. See also Moon and Solomon, 1984 (Fluid Inclusion Research, v. 17, p. 230) and Moon, 1985 (Fluid Inclusions Research, v. 18, p. 280). (E.R.)

MOON, K.J., 1989, REE patterns at the Sangdong tungsten skarn ore deposit, South Korea: J. Geol. Soc. Korea, v. 25, no. 3, p. 205-215. Author at Korea Inst. Energy and Resources.

Three exploration drillings exposed a granitoid emplaced in the Precambrian metasediment at a depth of ~500 m below the present W skarn orebody at the Sangdong mine. The variation patterns of rare earth elements (REE) shown by analysis of 10 cores of the granitoid exhibit similar patterns to the other Cretaceous granites in south Korea; they are characterized by containing a moderate Eu negative anomaly and do not show a regular variation with depth.

The limestone corresponding to the main orebody, the pyroxene-garnet skarn and the quartz-mica skarn show very similar REE patterns with characteristic moderate Eu negative anomalies and have clearly different content of REE, while the amphibole skarn has exceptionally no Eu anomaly and shows a different pattern. REE content of the limestone and all skarns except the amphibole skarn tends to increase with the evolution of the skarn formation and the range of Eu anomalies is almost the same between the skarn ores and the granite. Therefore, the REE patterns may tell a genetic order in the formation of the skarns and contribute to understanding the genesis of the skarn ore deposit at Sangdong mine. (Author's abstract)

MOORE, C.H., 1989, Carbonate Diagenesis and Porosity: Developments in Sedimentology 46, Elsevier Amsterdam, 338 pp. Author at Basin Research Institute, Louisiana State Univ., Baton Rouge, LA 70903-4101.

Includes a three-page summary of the use of fluid inclusions (p. 71-73). (E.R.)

MOORE, J.N. and **ADAMS, M.C.**, 1989, Fluid inclusion systematics of the Coso geothermal system, California (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 46. Authors at Univ. Utah Res. Inst., Earth Sci. Lab., 391 Chipeta Way, Suite C, Salt Lake City, UT 84108-1295.

Studies of active geothermal fields afford a unique opportunity to correlate fluid processes in shallow crustal environments with the evidence provided by FI. As a result of recent geothermal development, rock and fluid samples have now become available from many high-T geothermal systems. In this paper we present FI data for ten wells drilled at the Coso geothermal system, located on the eastern side of the Sierra Nevada Range 60 km west of Death Valley. The geothermal system occurs in Mesozoic granitic and metamorphic rocks that have been intruded and overlain by Quaternary rhyolite and basalt.

Chemical analyses of production fluids from 27 wells define steep gradients in salinities, gas concentrations, and T across the reservoir. Salinities and CO_2 contents range from 1.05 wt % TDS and 0.95 wt % CO_2 in the deep upflow zone located in the southern part of the field to 0.37 wt % TDS and 0.06 wt % CO_2 in shallow production zones located in the northern and eastern parts of the field.

FI data are in close agreement with the chemical data. Two-phase liquid-rich inclusions were studied in vein calcite, quartz, and anhydrite. Homogenization T (Th) of these inclusions are similar to the downhole measurements, indicating that the inclusions are contemporaneous with geothermal activity. Ice-melting T (Tm-ice) ranged from 0.0° to -2.8°C but individual samples typically displayed large variations. These variations and positive Tm CO_2 clathrate in some samples indicate that the inclusion fluids have significant but variable CO_2 contents.

Plots of Th vs. Tm-ice define a fluid mixing trend that includes the compositions of the production fluids. These relationships suggest that the deep upwelling fluid has a T of 325°C, and equivalent NaCl salinity of 1.4 wt %, and up to 2.4 wt % CO_2. Deviations of Tm-ice from the mixing trend reflect boiling and gas transfer between fluids. (Authors' abstract)

MOORE, J.N., HULEN, J.B., LEMIEUX, M.M., STERNFELD, J.N. and **WALTERS, M.A.**, 1989, Petrographic and fluid inclusion evidence for past boiling, brecciation, and associated hydrothermal alteration above the Northwest Geysers steam field, California: Geothermal Resources Council, Trans., v. 13, p. 467-472. First author at Univ. Utah Research Institute.

Many of the wells drilled in the Northwest Geysers have encountered thin, scattered zones of hydrothermally brecciated graywacke above the steam reservoir. The breccias are characterized by open-space fillings of quartz, calcite, adularia, albite, pyrite, and pyrrhotite. Secondary sericite occurs within the clasts. Fluid inclusion measurements indicate that the quartz and calcite formed from boiling fluids between 313° and 223°C. These fluids had estimated salinities ranging from 0.35 to 1.7 eq. wt % NaCl and variable but significant gas contents. Variations in the Th of these inclusions suggest that they record the downward movement of the water table with time. As the water table declined, slightly acidic condensate reacted with the breccias to produce sericite. (Authors' abstract)

MOORE, J.N., LEMIEUX, M.M. and ADAMS, M.C., 1989, The occurrence of CO_2-enriched fluids in active geothermal systems: Data from fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359-360. Authors at Univ. Utah Research Inst., Salt Lake City, UT 84108.

The condensation of CO_2 and steam in groundwaters above zones of boiling is thought to produce the Na bicarbonate fluids that are commonly found on the margins of high-T geothermal systems. Evidence for significant CO_2 flux has been found in fluid inclusions from the active geothermal systems at Los Azufres, Mexico, and Zunil, Guatemala. These geothermal fields are associated with recent volcanism and have maximum measured T close to 300°C.

CO_2-enriched fluid inclusions are widely distributed in both geothermal systems. These inclusions define a cap over each system that thickens outward from the high-T discharge zones. Fluid inclusions from the upper portions of the caps produce CO_2 clathrate upon freezing that melts at T ranging from 0°C to +2.6°C. CO_2 contents calculated from these melting T range from ~4 to 5 wt %. Tm ice indicate that inclusions from the lower portions of the caps are also enriched in gas but contain less than 4 wt % CO_2. The high concentrations of CO_2 in the inclusion fluids require that trapping occurred at P several tens of bars above hydrostatic. Differences between the trapping and hydrostatic P may reflect local reductions in fracture permeabilities produced by mineral deposition during boiling. (Authors' abstract)

MORA, C.I. and VALLEY, J.W., 1989, Halogen-rich scapolite and biotite: Implications for metamorphic fluid-rock interaction: Am. Mineral., v. 74, p. 721-737. First author at Dept. Geological Sciences, Univ. Tennessee, Knoxville, TN 37996.

Abundant Cl-rich scapolite and biotite indicate high Cl activities during greenschist- through amphibolite-facies regional metamorphism of metasedimentary rocks northwest of the Idaho batholith. Biotite-zone granofels contain up to 40 modal % Cl-rich scapolite. The strict stratigraphic control on the occurrence of scapolite and the fine-scale interlayering of Cl-rich and Cl-poor metasedimentary rocks suggest that scapolite was formed during regional metamorphism by reaction of plagioclase with calcite and halite. Mass-balance constraints on the formation of scapolite show that, prior to metamorphism, sedimentary units containing 10 modal % halite along restricted sedimentary horizons, 0.5 to 20 cm thick, would have been sufficient to form the most scapolite-rich layers. The abundance of Cl-rich phases decreases abruptly with the appearance of zoisite-bearing assemblages in the metasedimentary rocks, suggesting infiltration of low-Cl H_2O at higher grades. Scapolite compositions range from 32 to 62 eq. anorthite (EqAn) and 0.76 to 0.06 X_{Cl}. There is a general increase in EqAn and decrease in X_{Cl} with increasing metamorphic grade. However, local variations in scapolite composition suggest that metamorphic fluid compositions were heterogeneous and internally buffered. Biotites coexisting with scapolite contain up to 0.51 wt % Cl (biotite grade) and 2.58 wt % F (kyanite + sillimanite grade). Biotite compositions indicate significant differences in log (f_{HF}/f_{HCl}) values of fluids in equilibrium with low-grade, biotite- and carbonate-rich granofels. Differences in the inferred metamorphic fluid compositions are observed, in some cases, down to a scale of <1 cm.

Cl is strongly partitioned into an aqueous fluid relative to solid phases and is removed by metamorphic devolatilization and infiltration by dilute fluids. Therefore, the occurrence of buffered activity gradients in Cl, as indicated by scapolite and biotite compositions, suggests that metamorphic fluid flow was highly channelized and aqueous fluid-rock interaction was limited. High and variable Cl activities were not smoothed out by aqueous fluid-rock interaction through two regional metamorphic events. (Authors' abstract)

MORAVEK, P., JANATKA, J., PETROLDOVA, J., STRAKA, E., DURISOVA, J. and PUDILOVA, M., 1989, The Mokrsko gold deposit—the largest gold deposit in the Bohemian massif, Czechoslovakia, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 252-259. First author at Geoindustria, U pruhonu 32, Praha 7, Czechoslovakia.

The recently discovered Mokrsko deposit represents the largest Au deposit in the Bohemian massif. The deposit occurs in upper Proterozoic volcano-sedimentary rocks of the Jílové belt (640-700? Ma) and in granodiorite of

Hercynian age (320-360 Ma). Au-bearing quartz mineralization of vein and stockwork types is structurally and lithologically controlled. The lack of wall-rock alteration and the similar chemistry of amphibole and biotite from quartz veins and adjacent rocks suggest similar P-T conditions of origin. The T ranges obtained for the quartz veins (fluid inclusions: 250°-350°C; oxygen isotopes: 330°-420°C) and the T and P of the adjacent rocks (500°-630°C; $P <$ 0.4 GPa) indicate that the Au mineralization occurred in the same temperature ranges as epidote-amphibolite and lower amphibolite facies metamorphism. The rock geochemistry suggests a hydrothermal metamorphic mobilization of Au from upper Proterozoic rocks with a possible enrichment by magmatic fluids. (Authors' abstract)

MORITZ, R.P. and **CROCKET, J.H.**, 1989a, The crack-seal mechanism of veining as a trigger of H_2O-CO_2 fluid immiscibility and high grade gold-deposition in the Quartz-Fuchsite vein, Dome mine, Timmins area, Ontario (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359. First author at INRS-Géoressources, Univ. Québec, Ste-Foy, Quebec G1V 4C7, Canada.

The 500 m by 550 m by 3.5 m average thickness Archean-age Quartz-Fuchsite vein (QFV) is the highest grade ore body at the Dome mine. The vein is located in carbonatized komatiites at the contact with a unit of slates. It consists of massive and crack-seal type phyllosilicate-banded quartz material. The latter type carries the high Au concentrations of the QFV. Vein formation and Au mineralization predate the regional foliation and stretch lineation.

An early hydrothermal stage is composed of: low salinity CH_4-rich H_2O-CO_2 fluid inclusions; CO_2-CH_4 inclusions, probably containing an outer rim of H_2O; and low salinity (NaCl) H_2O inclusions. Coexisting H_2O-rich and CO_2-CH_4-rich inclusions in trails and clusters provide good evidence that intermittent phase separation took place in the H_2O-CO_2-CH_4-NaCl system. T conditions at trapping were around 300°C. Trapping of the carbonaceous-aqueous fluid predates the regional deformation, since inclusion trails of the first stage do not cross subgrain and recrystallized quartz grain boundaries. The timing and the similar composition of these fluid inclusions relative to the fluids that altered the wall rocks suggest that they represent the trapped Au-bearing fluid. Occasional NaCl-$CaCl_2$-bearing H_2O inclusions with Th between 110 and 144°C belong to a latter hydrothermal stage. These inclusions are unrelated to the mineralizing event.

The systematic affinity of high Au grades for banded quartz suggests a genetic link between the crack-seal mechanism of veining and Au deposition. The drop in fluid P at each crack-seal increment resulted in phase separation in the H_2O-CO_2-CH_4-NaCl system, with concomitant changes in fO_2 and pH, thus destabilization of Au complexes, and formation of the high grade ore zones in the QFV. (Authors' abstract)

MORITZ, R.P. and **CROCKET, J.H.**, 1989b, Mechanism and controls of ore deposition in the quartz-fuchsite vein at the Dome mine, Timmins, Ontario: Example of an efficient gold deposition process (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-120. First author at INRS-Géoressources, Univ. Quebec, Ste-Foy, Quebec G1V 4C7, Canada.

The 500 by 550 by 3.5 m average width quartz-fuchsite vein is the highest grade ore body of the Dome mine. It lies in a zone of completely carbonatized komatiites at the contact with a unit of slates.

A high pore fluid P regime that developed in the carbonatized komatiites in proximity of the slates resulted in hydraulic fracturing and genesis of the quartz-fuchsite vein. Massive and barren quartz was deposited during protracted stages of simple vein growth. Banded and Au-bearing quartz was formed during repetitive and brief periods of crack-seal vein growth.

FI studies indicate that the hydrothermal fluid contemporaneous with quartz veining and Au deposition was a low-salinity CH_4-rich H_2O-CO_2 fluid that underwent intermittent unmixing. Phase separation was promoted during P drops in fractures that accompany the crack-seal vein growth mechanism. The strong partitioning of CO_2 and CH_4 into the vapor during unmixing resulted in a shift in the remaining fluid towards higher pH and fO_2. As a consequence, Au complexes were destabilized in the hydrothermal fluid and deposited with quartz at each crack-seal increment. The P sensitive nature of the ore-bearing fluid combined with the multiple crack-seal events that are required to generate the large width of the banded domains of the vein are optimum conditions to form a high grade ore mineralization. (Authors' abstract)

MORRISON, J. and **VALLEY, J.W.**, 1989, Partitioning of F-Cl-OH between amphibole, apatite, and biotite in granulites from the Adirondack Mts., NY (abst.): Eos, v. 70, p. 493. First author at Dept. Geol. Sci., USC, Los Angeles, CA 90089-0740.

Halogen-rich amphibole, apatite and biotite occur in the Marcy anorthosite massif and adjacent charnockites in the Adirondack Mts. of New York.

Electron microprobe analyses indicate that amphiboles from the anorthosite are extremely Cl-rich (between 1.66 and 3.24 wt % Cl) and F-bearing (0.43 to 1.01 wt % F). Apatite which coexists with these Cl-rich amphiboles is generally fluor-apatite (2.83 to 3.39 wt % F) but may contain up to 0.89 wt % Cl. One unusually well characterized charnockite sample (see Bohlen et al., 1980) contains coexisting amphibole, biotite and apatite: the biotite contains 1.03 wt % Cl, and 0.33 wt % F, and the amphibole contains 1.53 wt % Cl and 0.13 wt % F.

Additional analyses of coexisting halogen-rich amphibole, apatite and biotite are being conducted in order to evaluate metamorphic fluid compositions calculated from two independent experimental determinations of partitioning between F-Cl-OH-biotite and F-Cl-OH-apatite. (From authors' abstract by E.R.)

MOSKOVSKY, G.A., GONCHARENKO, O.P. and **MAKAROV, A.S.**, 1989, Interpretation of the results of macro- and microcomponents in inclusion solutions and [in the] solid phase of minerals of saline sediments: Geokhimiya, 1989, (1), p. 61-67 (in Russian, English abstract).

The paper considers the conditions of sedimentation and diagenesis of the Kingur sediments of a number of areas of the Near-Caspian depression, from the composition of inclusion brines in halite as well as from Br and Cl contents in the inclusions and in the halogene rock itself. It has been shown that the composition of inclusions in sedimentary halite gives reliable information on the sedimentation conditions in the salt-producing basin. Br/Cl ratios are very helpful in determination of genesis of the K salts. (Authors' abstract)

MOTYKA, R.J., POREDA, R.J. and **JEFFREY, A.W.A.**, 1989, Geochemistry, isotopic composition, and origin of fluids emanating from mud volcanoes in the Copper River basin, Alaska: Geochimica Cosmochim. Acta, v. 53, p. 29-41. First author at Alaska Div. Geol. and Geophys. Surveys, 400 Willoughby Center, Juneau, AK 99811.

Analyses of waters and gases from the Copper River basin, Alaska, show marked differences in the fluid chemistries of two groups of mud-volcano saline springs. The Tolsona group discharges Na-Ca rich, HCO_3-SO_4 poor saline waters accompanied by small amounts of CH_4, N_2, and He. Tolsona gases have $^3He/^4He$ ratios of 0.75 to 2.7 (R/R_{atm}), $\delta^{13}C$-CH_4 values of -33 to -22‰, and $\delta^{15}N$ values of -1.8 to +1.6‰. The Klawasi group discharges Ca poor, Na-HCO_3 rich saline waters with large amounts of CO_2 and $^3He/^4He$ ratios of 2.6 to 4.1 (R/R_{atm}), $\delta^{13}C$-CO_2 values of -4.8 to -3.1‰, $\delta^{13}C$-CH_4 values of -23 to -18‰, and $\delta^{15}N$ of -3.5. Spring waters from both groups differ substantially from seawater composition. Compared to the Tolsona waters, the Klawasi waters are strongly enriched in Li, Na, K, Mg, HCO_3, SO_4, B, SiO_2, As and ^{18}O and strongly depleted in Ca, Sr and deuterium. The differences in fluid chemistry are attributed to the interaction of CO_2 with Tolsona-type formation waters. The CO_2 is thought to be derived from a deep-seated magmatic intrusive and contact decarbonation of limestone beds underlying the Klawasi area. (Authors' abstract)

MOURA, A., DUBESSY, J. and **NORONHA, F.**, 1989, Quartz characterization in a potential auriferous area, Northern Portugal (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 69-70. First author at Centro de Geol. da Univ. do Porto (INIC), Fac. de Ciencias, 4000 Porto, Portugal.

A comparative study of mineralized and barren quartz veins from Curros (Valpacos) Northern Portugal has been undertaken. Both mineralized and barren quartz veins occur in the same geological environment. The surrounding country rocks are metasediments of Silurian age, dominantly made up of quartzose phyllitic rocks, micaschists and black shales. The rocks have suffered low grade regional metamorphism (P from 3 to 4 kbar and $T \approx 500°C$). The mineralized veins of the Vale de Campo Pb old mine are subvertical with a strike ranging from N 30° E to N 50° E. The barren veins of Cabeco do Seixo are also subvertical with a strike ranging from NNW-SSE to NNE-SSW. Both orientations are typical of the Hercynian in N. Portugal. Three stages of ore deposition can be identified in the mineralized veins: (i) arsenopyrite, pyrite and pyrrhotite; (ii) sphalerite, chalcopyrite, Cu sulphosalts and galena I; and (iii) electrum, galena II and Ag sulphosalts.

Arsenopyrite, pyrite and galena are the main opaque minerals. Electrum occurs within pyrite and along sulphides boundaries, mostly associated with galena II and the Ag sulphosalts. Several kinds of quartz can be recognized in the mineralized veins. Quartz associated with Au mineralization is the youngest and occurs as slightly deformed hyaline crystals. Two contrasting CO_2-H_2O-bearing fluids (B_1 and B_2) are represented in P inclusions. The fluid compositions, determined from microthermometric and Raman spectroscopic data are as follows: *Type B_1* bulk density = 0.92 g/cm^3, salinity = 5.0 wt % NaCl eq., molar volume = 26 cm^3/mole, X(H_2O) = 80 mole %, X(CO_2) = 16 mole %, X(NaCl) = 4 mole % and X(CH_4) = 0.2 mole %; and *Type B_2* bulk density = 0.85 g/cm^3, salinity = 4.0 wt % NaCl eq., molar volume = 35 cm^3/mole, X(H_2O) = 57 mole %, X(CO_2) = 40 mole %, X(NaCl) = 2 mole % and X(CH_4) = 1 mole %. Bulk homogenization of these two fluids occurs at 330°C (B_1) and 325°C (B_2).

Deposition of the Au mineralization is probably associated with a drop in P. Oxygen fugacity is around Ni-NiO buffer (10^{-32} at 330°C). CO_2 and CH_4 components arise from the surrounding metasediments where C-rich material is well represented. The barren quartz of Cabeco do Seixo has a zoned subvertical structure. No carbonic component has been detected by microthermometry and crushing experiments. Primary fluids have a low salinity (2.5 wt % NaCl eq.) and have The L ~234°C.

The similarity between salinity and CO_2 density of the B_1 and B_2 fluids does not suggest the unmixing of an homogenous fluid generating the two contrasting fluids. Instead, a mechanical mixture of CO_2-H_2O fluids is proposed. While mineralized veins are synorogenic the barren ones are postorogenic. There is no evidence for thermal metamorphism. A metamorphic origin for the mineralized fluids is therefore proposed. (Authors' abstract)

MULLIS, J., 1989, Worldwide fluid immiscibility in the CH_4-H_2O-salt system during very low-grade metamorphic conditions (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 71. Author at Mineral.-Petrogr. Inst. der Univ., Basel, Switzerland.

Worldwide, methane-water immiscibility is a common feature in very low-grade metamorphic terrains. Coexisting water-rich and methane-rich fluids in rocks indicate fluid unmixing during prograde and retrograde metamorphism. Important factors causing methane-water unmixing are: (i) T-decrease during retrograde conditions; (ii) P-decrease caused by tectonics and fluid overpressure; (iii) methane-increase due to cracking of kerogen and higher hydrocarbons during T increase; and (iv) salt-increase due to salt dissolution of salt input by fluid migration (salting out).

In addition, vertical movements of the gas-water interface can mimic unmixing processes. As FI in minerals trapped during prograde conditions are rarely preserved, fluid unmixing processes are well documented during maximum T and retrograde conditions. Therefore, the dominant fluid unmixing processes are T-decrease and repeated P drops of at least 0.5 to 1.5 kb. (Author's abstract)

MULTHAUP, R.A. and **WALKER, G.P.L.**, 1989, Nature and causes of pipe vesicles in Hawaiian basalts (abst.): Eos, v. 70, p. 1422.

MURAMATSU, Yoichi, 1987, Fluid inclusion study of Matsukawa geothermal field (abst.): Abstracts, Joint Mtg. Min. Soc. Jap./Soc. Min. Geol. Jap./Jap. Assoc. Min., Pet., Econ. Geol. (in Japanese, translated by Y. Seki). Author at New Energy Fund.

Fluid inclusions were studied in quartz, calcite and anhydrite from core cuttings in the Matsukawa geothermal field, a vapor-dominated system. Based on minimum Th (Th,min), high T zones indicated by Th,min >220°C are recognized. Liquid and vapor phase inclusions, indicating boiling, are observed in a large number of samples. Fluid inclusions with vapor phase are especially dominant in the high T zones. Th,min increases rapidly with depth to 350-500 m, but in the deeper part Th,min shows no change with depth. Therefore, the portion shallower than 350-500 m is considered to be a cap rock. Present T at depth are 13-38°C higher than that of Th,min at the depth of wairakite appearance (=200-220°C). This means the aquifer T has increased, resulting in anhydrite, quartz and pyrophyllite deposition, after wairakite precipitation. (Author's abstract)

MURAMATSU, Yoichi, MIYAZAKI, Shin-ichi and **SATO, Ko**, 1989, Estimation of an areal extent of geothermal reservoir by new techniques of exploration in the Kakkonda geothermal area: Mining Geol., v. 39(4), p.

239-251 (in Japanese, English abstract). First author at New Energy Foundation, 1-18-1, Toranomon, Minato-ku, Tokyo 105, Japan.

Attempts have been made to confirm the extension of geothermal reservoir by new techniques of exploration such as fluid inclusion survey and AE (acoustic emission) method in the Kakkonda (Takinoue) geothermal area.

It is necessary to estimate the borehole T for the evaluation of the geothermal resource of each well. The minimum Th of the S inclusions in quartz and calcite is useful to make prediction of the underground T, because the minimum Th is in good agreement with the measured downhole T by logging. In order to measure the T around fractures during drilling without delay, we developed a measuring apparatus for fluid inclusions in minerals without making polished sections ourselves, using a silicon oil-filled cell. The lateral distribution of the Th shows that high T zone exists in the northwestern part of the Kakkonda area.

An acceleration sensitive long-distance AE measurement technique has been successfully applied to study the behavior of fracture extension caused by a build--up test, hydraulic fracturing treatments and drilling. (...)

It has been revealed on the basis of the new techniques of exploration described here that the geothermal reservoir in the Kakkonda area extends to the northwestern part of this area. A 35% of production steam is now obtained around D and E bases. (From authors' abstract by E.R.)

MUSGRAVE, J.A. and **NORMAN, D.I.**, 1989, Initial results of fluid inclusion studies from Continental Scientific Drilling Program corehole VC-2A, Valles caldera, New Mexico (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 47. First author at ESS-1, Los Alamos Nat'l. Lab., MS D462, Los Alamos, NM 87545.

Corehole VC-2A is the second corehole drilled as part of the Continental Scientific Drilling Program at Sulphur Springs, Valles caldera, New Mexico. FI in quartz have been analyzed by mass spectroscopy. Th of FI in quartz, from 33 to 95 m in VC-2A, average about 225°C. Tm ice data indicate an average salinity of 2.5 eq. wt % NaCl. Gaseous species measured were CO_2, H_2S, CH_4, Ar, N_2, He, and numerous organic species up to and including C_6. The mole % gaseous species in the analyzed inclusion is 3 to 9; CO_2/H_2S ratios vary from almost 1:1 to 100:1.

The high gas-to-water ratio is interpreted to be from analysis of a mixture of liquid-filled and vapor-filled inclusions. Petrographic studies indicate numerous vapor-filled inclusions. This together with the gas data suggest that the minerals were deposited from a boiling fluid. The high H_2S fluid may have been evolved from the intrusive body that underlies the Jemez Mountains. The low H_2S fluid has gaseous species in similar ratio to the deep geothermal water in the Valles hydrothermal system. The minerals hosting predominantly CO_2-bearing fluids we suggest were deposited by deep Valles reservoir water, and the data suggest that two fluids have been active in the Sulphur Springs area in the recent past. (Authors' abstract)

NABELEK, P.I. and **LABOTKA, T.C.**, 1989, The implications of petrologic and isotopic fluid/rock ratios for the contact-metamorphism of calc-silicates (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A84.

NADEAU, S., 1989, Carbon degassing from the Earth's interior through geological time (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-30.

NADEAU, S. and **FRANCIS, D.**, 1989, Volatile and trace element contents in magmas derived from variable mantle source compositions (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-22. Authors at Dept. Geol. Sci., McGill Univ., 3450 University St., Montreal, H3H 2A7, PQ, Canada.

Volatile contents in mantle-derived magmas have generally been obtained from basaltic glasses which were thought to have cooled rapidly enough to preserve their primary abundances. However, a recent experiment (Stolper and Fine, Eos 1988) indicates that such magmas have suffered various extents of degassing during migration to the surface which restricts the usefulness of glass compositions as indicators of the volatile contents in magmas and mantle sources. In this study, we evaluate the concentration of volatiles in mantle-derived magmas using volatile contents measured in mantle xenoliths ranging from anhydrous to amphibole-bearing spinel lherzolite, harzburgite and pyroxenite. In these calculations CO_2 and H_2O are considered to behave as incompatible elements during the melting of anhydrous mantle sources, but H_2O is considered as a compatible element during the melting of hydrated mantle sources. Our models indicate that N-MORB and E-MORB will contain from 10 to 100 ppm C and 0.06 to 0.27% H_2O if they are derived by 10 to 15% melting of anhydrous mantle sources. Olivine tholeiites and alkaline basalts from Nunivak Island will have 80 and 420 ppm C with 0.36 and 1.57% H_2O if they are derived by 25 and 5% melting respectively, of trace element enriched mantle sources. More alkaline magmas (kimberlite and carbonatite) thought to be derived from deeper mantle sources and lower degrees of melting require higher CO_2 contents than have been measured in FI trapped in mantle xenoliths. This suggests the involvement of an additional carbon-rich phase such as carbonate, graphite and/or diamond. (Authors' abstract)

NADEN, J. and **CAULFIELD, J.B.D.**, 1988, Fluid inclusion and isotopic studies of gold mineralization in the Southern Uplands of Scotland: Trans. IMM, Sect. B, v. 98, p. B46-B48. First author at BP Minerals Int'l, Ltd., Newbury, Berkshire, England.

These prospects can be divided into two groups: sediment/granodiorite/diorite-hosted and deposits that are entirely granite-hosted. In all cases early quartz-pyrite-arsenopyrite with minor amounts of Au is followed by a later base-metal mineralization. Silicate minerals in zones of hydrothermal alteration are enriched in $\delta^{18}O$ compared to minerals in unaltered intrusions. The O isotope data are interpreted as indicating the interaction of a fluid of constant composition that resulted from interactions with the country rocks and are consistent with a pattern of a shift in isotopic composition with increasing time and decreasing T. The S isotope ratios suggest that sulphide sulphur was derived from both the intrusion and the host strata.

FI in quartz veins associated with mineralization show four types. Type I aqueous, two-phase (L + V) inclusions have Th and salinities of 84-348°C and 0.28-12.42 eq. wt % NaCl; Type II aqueous, two-phase (L + V) inclusions exhibit clathrate melting, indicating a dissolved gas (e.g., CO_2, CH_4, N_2), and Th and salinity 161-365°C and 1.23-15.5 eq. wt % NaCl; type III inclusions are H_2O +CO_2 with Th and salinities 190-250°C and 0-9.24 eq. wt % NaCl, 0.007 and 0.84 mole % CO_2; type IV are predominantly composed of methane. Thermometric data for type III inclusions and the composition of the different types of inclusion indicates that extensive fluid unmixing *did not* take place during mineralization. (From authors' abstract by E.R.)

NADEN, J. and **SHEPHERD, T.J.**, 1989a, Mineralogical and fluid inclusion characteristics of gold mineralization, Southern Uplands, Scotland, UK (abst.): Terra abstracts, v. 1, p. 26.

Fluid inclusion analysis of quartz veins associated with the mineralisation reveals the presence of three main types of inclusions: (i) aqueous two phase (L+V) inclusions with Th and salinities in the ranges 84 to 348°C and 0.28 to 12.42 wt % NaCl eq.; (ii) aqueous two phase (L+V) inclusions that exhibit clathrate melting, indicating the presence of a dissolved gas (e.g., CO_2, CH_4, N_2) with Th and salinities in the ranges 161 to 365°C and 1.23 to 15.5 wt % NaCl eq.; and (iii) carbonic 2/3 phase inclusions comprising liquid H_2O + CO_2 plus CO_2 vapour, or liquid H_2O plus CO_2 vapour. Type (iii) inclusions have Th and salinities in the following ranges: 190 to 250°C and 0 to 9.24 wt % NaCl eq., CO_2 contents between 0.007 and 0.84 mol %.

A metallogenic model will be presented that compares and contrasts the fluids associated with gold mineralization in the Southern Uplands and North Wales, and which may have more general applications to Au deposits in low to medium grade metamorphic terrains, where fluid immiscibility is an important feature of the systems. (From authors' abstract by E.R.)

NADEN, Jonathan and **SHEPHERD, T.J.**, 1989b, Role of methane and carbon dioxide in gold deposition: Nature, v. 342, p. 793-795. Authors at British Geol. Surv., 64 Grays Inn Road, London WC1X 8NG, U.K.

Vein-hosted Au deposits in low- to medium-grade metamorphic terrains are commonly associated with low-salinity hydrothermal fluids rich in CO_2 and/or CH_4. FI studies of gold mineralization indicate that the ore fluid comprised coexisting CO_2/CH_4-rich and H_2O-rich phases, and that phase separation played an integral part in Au deposition. In hydrothermal solution Au is present as the $Au(HS)^-_2$ complex. Precipitation of Au caused by decreasing ligand activity involving the formation of Fe sulphides from wall-rock Fe oxides and silicates is clearly relevant to Au deposits associated with Fe formations and Fe-rich igneous rock. It cannot, however, be used to explain the common association of Au deposits with black shales or schists, where wall-rock Fe is in the form of sulphides, and therefore generally in equilibrium with the hydrothermal fluid, or with granitoids or felsic volcanics, where the amount of Fe is low. This latter association may be explained by the partitioning of H_2S into the non-aqueous phase during fluid immiscibility, but the general applicability of this mechanism is not known. Here we present a new synthesis of experimental data from a variety of sources which puts this mechanism on a semi-quantitative basis, and suggest that it may be applicable to a wide variety of hydrothermal Au environments. (Authors' abstract)

NAESER, N.D. and **NAESER, C.W.**, 1989, Fission tracks in basin analysis (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-488-489.

NAIK, M.S., 1989, Genesis of the copper deposit at Malanjkhand, Madhya Pradesh: Indian J. Earth Sci., v. 16, no. 1, p. 27-37. Author at Dept. Applied Geology, Indian School of Mines, Dhanbad 826004.

Cu mineralisation in the Precambrian granodiorite pluton at Malanjkhand is confined to a metasomatised zone within the pluton. Statistical petrographic study of the granodiorite and metasomatised granodiorite indicates successive periods of solid-fluid interactions.

Geochemical data of the granodiorite suggest that it was formed from an anatectic magma which is considered to have been derived by partial melting of crustal rocks. The geochemical interactions within the pluton indicate the presence of abundant fluids during magmatic evolution of the pluton. REE study supports migration of the hydrothermal solutions derived by *in situ* differentiation of the granodiorite magma and their subsequent interactions within the parental pluton.

The above-normal concentration of Cu in the granodiorite supports the view that the magma was relatively rich in Cu and was the source for the Cu mineralisation. The source of Cu was the precursor rocks of the deeper crust, melting of which favoured entry of the Cu into the melt. During differentiation of the magma, residual late stage fluids were further enriched in Cu. It is suggested that the geochemical interactions between these fluids, which were selectively enriched in mineraliser, and the parent granodiorite have resulted in the deposition of Cu ore. Fluid inclusion studies have shown that the Cu deposit was formed between 210° and 475°C from hydrothermal fluids that underwent resurgent boiling within the range 305°-475°C. (Author's abstract)

NAKANO, Takanori, KAJIWARA, Yoshimichi and **FARRELL, C.W.**, 1989, Strontium isotope constraint on the genesis of crude oils, oil-field brines, and Kuroko ore deposits from the Green Tuff region of northeastern Japan: Geochim. Cosmochim. Acta, v. 53, p. 2683-2688.

NAKANO, Takanori and **URABE, Tetsuro**, 1989, Calculated compositions of fluids released from a crystallizing granitic melt: Importance of pressure on the genesis of ore forming fluid: Geochem. J., v. 23, p. 307-319. First author at Inst. Geoscience, Univ. Tsukuba, 1-1-1 Tennoudai, Tsukuba 305, Japan.

Chemical compositions of magmatic fluids released from a water-saturated, crystallizing granitic melt are calculated quantitatively. The calculations were performed using the model originally proposed by Holland (1972) incorporating currently available experimental partition coefficient data. The results indicate that the partitioning of metal cations into the fluid phase is strongly dependent on P, their fluid-melt partitioning coefficients and Cl content in the initial granitic melt.

Concentration of Cl and most cations in the fluid phase will generally increase at $P < 1$ kbar, whereas decrease above it, with the progress of crystallization. While crystallization of a granitic magma over a wide range of P will yield a fluid phase with high concentration of Na and K compared to Ca, enrichment of the fluid in Pb and Zn will likely occur if the fluid release occurs at $P < 1$ kbar. The calculation suggests that the initial granitic magma should contain Cl at least in a range of 200-1000 ppm to transport base metals into the aqueous phase effectively. The calculations reported in this study strongly support the validity of the classical hypothesis that Cl-rich magmatic fluids evolved at shallow depths (<2 kbar) have the potential of forming hydrothermal base metal deposits. (Authors' abstract)

NAKANO, Tsukasa and FUJII, Naoyuki, 1989, The multiphase grain control percolation: Its implication for a partially molten rock: J. Geophys. Res., v. 94, no. B11, p. 15,653-15,661.

NANYARO, J.T., 1989, Proterozoic gold-base metal veins in the Mpanda mineral field, western Tanzania: Annales du Musee royale de l'Afrique centrale, Serie in 8, Sciences geologiques, no. 97. Author at Le Musee, Tervuren, Belgium.

Consists of 10 chapters, covering geology, alteration, S, Sr, and Pb isotopes, and one (no. 7) entitled "Fluid Inclusion Studies." (E.R.)

NAUMOV, G.B., KHITAROV, D.N. and SHAPENKO, V.V., 1989, Fluid inclusions section of the Scientific Council of the USSR Academy of Sciences on Ore Formation: Geokhimiya, 1989, (9), p. 1375 (in Russian).

A review of the status of FI research. (E.R.)

NAUMOV, G.B., MORONENKO, M.V. and SALAZKIN, A.N., 1988, Ore-formation at the geochemical degassing threshold: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 38-39 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci. U.S.S.R., Moscow, U.S.S.R.

Periods of ore precipitation frequently follow heterogenization of mineral-forming fluids connected with P decrease in tectonic zones. Analysis of the fluid inclusion data indicates this coincidence in 10-30% of the studied ore bodies. A low-T U vein deposit located in granites was chosen as an example. Th and chemical composition of inclusion fluids were studied in PS inclusions in metasomatic quartz. The outer metasomatic zone consists of a quartz-carbonate-hydromica rock with almost complete absence of Na, the inner zone of albite and hematite with pitchblende. CO_2 and Na are the main components of the ore-forming fluids, and their concentration gradually decreases from the hydromica zone (CO_2 5.1, Na 0.8 mole/kg H_2O) through albites (2.5 and 0.3) to vein quartz of the ore zones (1.5 and 0.25, respectively). K and Cl are distinctly subordinate. The central ore zone bears inclusions indicating boiling of solutions. Th in all zones are similar. The granite alterations were caused by a CO_2-rich solution leaching Na and yielding the hydromica zones. CO_2 loss resulted in alkalinity increase of the solution and albite formation. (A.K.)

NAUMOV, V.B. and NAUMOV, G.B., 1988, Heterogenization processes of natural fluids and their role in hydrothermal mineral formation: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 7 (in Russian). Authors at Inst. of Geochem. and Anal. Chem., Moscow, U.S.S.R.

A review of the data on processes of natural heterogenization of mineral-forming solutions, published in the world literature, has been made by the authors. Analysis of the fluid inclusion data obtained from 10,635 samples (40 mineral species) proves a common occurrence of heterogenization of fluids indicated by 10.5% of the reviewed cases. Data from 4633 samples of quartz have shown that the heterogeneous state is distinctly more common at higher T: 20-200°C gave heterogenization in 8.3% cases, 200-400°C in 19.2% cases and 400-600°C in 31.2% cases. Distinct P change causes a variation in local pH and redox values in mineral-forming media, being the reason of the contrasting geochemical conditions at short distances. (From the authors' abstract, translated by A.K.)

NAUMOV, V.B., SOLOVOVA, I.P., KOVALENKO, V.I. and GUZHOVA, A.V., 1989, Conditions of crystallization and peculiarities of composition of the melt inclusion phases in anorthoclase of agpaitic trachytes of Pantelleria Island, Italia: Geokhimiya, 1989, no. 1, p. 207-215 (in Russian, English abstract).

Using optic, cryo- and thermometric techniques as well as determinations of composition of glasses and crystalline phases by electron microprobe, the melt and fluid inclusions in phenocrysts of anorthoclase of agpaitic trachytes belonging to typical bimodal hawaiite-pantellerite association have been studied. Fluorite, halite, salt globules and amphibole-like crystals with unusually high content of ZrO_2 (0.3 to 3.7 mass %) have been found in the melt inclusions. Two generations of fluid inclusions have been revealed in which only CO_2 was found and fluid P at the moment of anorthoclase crystallization (250 to 120 and 24 to 9 bar) was determined. T of complete homogenization of the inclusions (1020 to 930°C) and crystallization of fluorite (890-740°C) have been found. Compositions of the homogeneous melts have been determined and for them the water content (2 mass %) and concentrations of Cl (0.6-1.2 mass %), F (0.3-0.6 mass %) and ZrO_2 (0.3-0.6 mass %) have been estimated. (Authors' abstract)

NAUMOV, V.B., SOLOVOVA, I.P., KOVALENKO, V.I., MALOV, V.S., TURKOV, V.A. and **SAMOILOV, V.S.**, 1988, Natural phosphate-sulphate melts: Dokl. Akad. Nauk SSSR, 1988, v. 300, no. 3, p. 672-675 (in Russian).

The P inclusions in apatite crystals from the Mushugai-Huduk carbonatite complex (Mongolia), have been investigated. The natural phosphate-sulphate melts were determined and their basic characteristics were calculated. The inclusions (20 to 170 μm) consist of two crystals, mainly apatite and anhydrite. In addition, ore and fluid phases are sometimes found. Sometimes the apatite phase has distinct zones. Microprobe analysis has demonstrated an essential difference in the composition of host and inclusion apatite. Thus Ce_2O_5 and La_2O_5 [sic] in the host-apatite range from 1.30 to 1.80 and 0.50-1.00 wt %, while in the inclusion apatite the corresponding values are 2.08-4.20 and 0.73-2.14 wt %. SiO_2 behaves similarly: host apatite 0.71-1.50 wt % vs. inclusion apatite 1.63-3.57 wt %. The thermometrical investigations are evidence of high T of the crystallization of apatite. The beginning of melting is fixed at only 1130-1150°C. Th occurred in salt melt at 1240-1290°C. Quenching over 2-3 sec results in crystallization of the melt.

The composition of the salt melt was estimated from the volumes of apatite and anhydrite in the inclusions and the composition of these phases. This salt melt took part in the crystallization of apatite. A typical apatite:anhydrite ratio (60:40-30:70) would yield (wt %): 47.5-45.6 CaO; 22.1-37.6 SO_3; 22.2-11.5 P_2O_5; 2.9-1.1 Ce_2O_5; 0.9-0.5 La_2O_5; 1.8-0.9 SiO_2; 1.8-0.9 F; 0.8-1.1 SrO; 0.3-0.2 Na_2O; 0.2 H_2O. Density of the melt is 2.9 g/cm^3. (Abstract by T. Sushchevskaya)

NAVON, O., SPETTEL, B., HUTCHEON, I.H., ROSSMAN, G.R. and **WASSERBURG, G.J.**, 1989, Micro-inclusions in diamonds from Zaire and Botswana (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 69-72.

Ten new ion-microprobe analyses are reported, plus data on Cl/K and REE. The major elements do not agree with kimberlite ratios. (E.R.)

NAYLOR, H., TURNER, P., VAUGHAN, D.J., BOYCE, A.J. and **FALLICK, A.E.**, 1989, Genetic studies of red bed mineralization in the Triassic of the Cheshire Basin, northwest England: J. Geol. Soc., London, v. 146, p. 685-699. First author at Dept. Geological Sciences, Aston Univ., Aston Triangle, Birmingham B4 7ET, U.K.

The Triassic sediments of the Cheshire Basin are host to a number of small mineral deposits characteristic of red beds. The mineralization comprises Cu and Pb with minor Zn, Ag, Co, V, Ni, As, Sb and Mn which, together with widespread barite mineralization, is closely associated with basin margin faults. The Wilmslow Sandstone Formation is cemented by authigenic quartz overgrowths enclosing iron sulphides, which predate the main sulphide cements of tennantite, bornite and sulpharsenides. Studies on late calcic-hosted fluid inclusions show Th ranging between 60-70°C (regarded as the minimum T of mineralization) and salinities of 9-22 wt % eq. NaCl (mean = 17 wt %), indicating that the mineralizing fluids were warm and saline. Consideration of the basin history suggests that fluid T in the Permo-Triassic sequence may have reached 150°C at the time of mineralization. New data significantly constrain the genetic hypothesis for the deposits, refuting a magmatic origin. A basin brine expulsion model is favoured. The sulphur isotope data from the barite mineralization (mean $\delta^{34}S = +17‰$) suggest that the bulk of the barite sulphur was derived directly from the Upper Triassic evaporites (mean $\delta^{34}S = +19‰$), whilst the distribution of $\delta^{34}S$ values for sulphides (-1.8‰ to +16.2‰) is consistent with ultimate derivation of sulphur from the evaporites by closed system reduction of a sulphate-bearing brine. It seems likely that the reducing agent was organic material (methane) derived from the underlying Coal Measures, but it is uncertain at present whether the principal mechanism was thermochemical or bacterial reduction. The pattern of sulphide $\delta^{34}S$ favours the former process. (Authors' abstract)

NEAL, C.R. and DAVIDSON, J.P., 1989, Are megacrysts involved in petrogenesis of magma in which they are entrained? Evidence from Malaitan alnoite (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-499.

NEAL, C.R. and TAYLOR, L.A., 1989, Metasomatic products of the lunar magma ocean: The role of KREEP dissemination: Geochimica Cosmochim. Acta, v. 53, p. 529-541.

A discussion of when and how immiscibility occurred in the history of formation of KREEP fluids. (E.R.)

NEHLIG, P., 1989, Supercritical two-phase separation of hydrothermal fluids in the Semail Ophiolite (abst.): Eos, v. 70, p. 1396. Author at School of Oceanography WB-10, Univ. Washington, Seattle, WA 98195.

The Semail Ophiolite forms a huge thrust sheet of Cretaceous oceanic lithosphere and exhibits the effects of an intense hydrothermal metamorphism. Within the extrusives lie massive Fe-Cu-Zn sulphide deposits formed by Cretaceous seafloor hydrothermal activity. These deposits and associated stockworks are rooted in Cu-Zn depleted epidosite-rich zones which extend to the transition zone between the plutonic sequence and the sheeted dike complex. This transition zone is characterized by a sharp downward decrease in hydrothermal activity and vein density, and by the occurrence, within plagiogranites, of four major FI families trapped in the same fracture arrays: (A) low to medium salinity (1.9 to 8.0 wt % NaCl eq.; mean = 3.8 wt % NaCl eq; N = 21) liquid/vapor FI which homogenize into the liquid phase at 213 to 429°C (mean = 287°C; N = 49); (B) low salinity (1.0 wt % NaCl eq.; N = 1) liquid/vapor FI with pseudocritical homogenization at 402°C (N = 1); (C) low to medium salinity (3.7 to 4.3 wt % NaCl eq.; mean = 4.0 wt % NaCl eq.; N = 2) liquid/vapor FI which homogenize into the vapor phase at 390 to 452°C (mean = 410°C; N = 5); (D) high salinity (40.0 to 52.0 wt % NaCl eq.; mean = 46 wt % NaCl eq.; N = 10) liquid/vapor/halite FI which homogenize into the liquid phase by halite disappearance at 230 to 404°C (mean = 298°C; N = 11).

These S FI are interpreted as resulting from two-phase separation of hydrothermal or magmatic fluids within the transition zone between the hydrothermal system and the magma chamber at >500°C (assuming a hydrostatic P of 410 bars) or >600°C (assuming a lithostatic P of 770 bars). The fluids must have suffered modifications between unmixing and becoming trapped in I. A combination of partial re-mixing, mixing with a cooler fluid and conductive cooling may account for the FI characteristics.

This process (i.e., phase separation and mixing) may explain the range of salinity observed in black smoker fluids. (Author's abstract)

NEHLIG, P. and JUTEAU, T., 1989, Fossil oceanic hydrothermal systems processes and their interactions with tectonic and magmatic activity (example of Semail ophiolite, Oman): Comparison with other ophiolitic and oceanic data (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-503-504. Authors at Université de Bretagne occidentale, Brest, France.

A detailed study of the crustal sequence of the Cretaceous Semail nappe at the latitude of the Haylayn Block (Central Oman Mountains), completed by data from several other blocks, allows us to study the geometry and the evolution with time of the hydrothermal circulation in a fossil oceanic crust.

Petrological and mineralogical data show that the whole crust, down to the petrological Moho, has been affected by a hydrothermal metamorphism, pervasive in the volcanic units and sheeted dike complex, and more localized around fractures in the underlying pluton units. The upper volcanic units are overprinted by a zeolite facies metamorphism whereas the lower volcanic unit and the sheeted dyke complex exhibit a greenschist facies. The underlying plutonic units (high-level gabbros, laminated and layered gabbros) are characterized by a transition to amphibole facies metamorphism.

The whole crust is cross-cut by a dense net of hydrothermal veins. These veins are the fossil record of fracture networks through which hydrothermal fluids once flowed. Diffusing from these veins modified seawater penetrated the surrounding rocks and induced retrograde metamorphic reactions. Three major episodes of hydrothermal circulation could be distinguished:

Early, accretion stage, circulations at the top of the magma chamber: Downflowing liquids (seawater) were heated at the top of the magma chamber up to 400°C, ascended adiabatically through the sheeted dyke complex and volcanic units, and exited at the seafloor constructing huge, oceanic type, massive sulfide deposits. Below the massive sulfide deposits lie stockwork-mineralized zones that can be traced down to the top of the sheeted dyke complex. These zones are characterized by quartz/sulfide veins formed when hot ascending solutions mixed with colder downflowing seawater as recorded by the dispersion in fluid inclusion Th. They are rooted in epidosite-rich zones, depleted in Cu/Zn, and which supplied the metals for the sulfide deposits. Fluid inclusion Tt indicate that the episodization took place between 330 and 400°C. Furthermore, it is characterized by boiling of fluids as deduced by fluid inclusion studies at T >420°C.

Seawater penetration and circulation in the just crystallized magma chamber: This episode is characterized by the development of a dense net of subparallel millimeter-thick closely spaced black amphibole veins (chlorine-rich actinolite to actinolitic hornblende). P fluid inclusions in amphiboles from the plutonic unit record Tt (hydrostatic P) around 500°C, approaching cracking front conditions.

Late "off-axis" circulations in the whole crust: This episode is characterized by epidote, prehnite, and calcite veins in the plutonic sequence, by prehnite and calcite veins in the sheeted dyke complex, and by zeolite and calcite veins in the volcanic extrusive unit. These circulations were active in the sheeted dyke complex until the sheeted dyke and plutonic sequence cooled to 160°C. (From authors' abstract by E.R.)

NEIVA, A.M.R., NEIVA, J.M.C. and SILVA, M.M.V.G., 1989, Geochemistry of gold quartz vein walls from Jales (northern Portugal) (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-504. Authors at Univ. Coimbra, Coimbra, Portugal.

Temperatures listed for various stages of the mineralization (480-100°C) may be Th values. (E.R.)

NEKRASOV, I.Ya. and NOVIKOV, M.P., 1989, Silver distribution between salt fluid and melts of liparite, andesite and basalt composition: Doklady Akad. Nauk SSSR, v. 309, no. 5, p. 1192-1196 (in Russian). Authors at Far-East Geol. Inst., Vladivostok, U.S.S.R.

The experiments indicate that saline high-T fluids are able to mobilize from silicate melts an amount of ore components including Ag sufficient for formation of rock ore bodies of the bonanza type. Pertinent to studies of inclusions of saline brines and melts. (A.K.)

NESBITT, B.E., CAVELL, P.A. and MUEHLENBACHS, K., 1989, Isotopic characteristics of the McDame gold-silver deposits, Cassiar District, British Columbia, *in* Current Research, Part E, Cordillera and Pacific Margin: Geol. Surv. of Canada, Paper 89-1E, p. 5-11. First author at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

$\delta^{18}O$ investigations of quartz veins from the Sylvester allochthon indicate that mineralized and unmineralized quartz veins have similar, ^{18}O-enriched values of +15 to +18‰. Late, crosscutting carbonate veins are depleted in ^{18}O with $\delta^{18}O$ values close to 0‰. δD data from fluid inclusions indicate that the quartz veins formed from meteoric water that had undergone extreme ^{18}O enrichment. The ^{18}O enrichment is believed to be a product of water/rock interaction between the meteoric water and metasedimentary rocks. (From authors' abstract by E.R.)

NESBITT, B.E. and MUEHLENBACHS, Karlis, 1989a, Constraints on depth of surface water convection during metamorphism and deformation in the Canadian Cordillera (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A85.

NESBITT, B.E. and MUEHLENBACHS, Karlis, 1989b, Geology, geochemistry, and genesis of mesothermal lode gold deposits of the Canadian Cordillera: Evidence for ore formation from evolved meteoric water, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 553-563. Authors at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

To date, mesothermal lode Au deposits have constituted the principal source of lode and placer Au in the Canadian Cordillera. In addition, these deposits are significant to the understanding of the genesis of Au deposits in general, since they are young analogues of the larger, more enigmatic Archean deposits.

In mesothermal Au deposits of the cordillera, Au-Ag ratios are typically greater than 1.0, and enrichments in As, B, Ba, W, Sb, Hg, and S are common. FI studies indicate formation T of 250° to 350°C and P of 1.0 ± 0.3 kbars, with high CO_2 contents and low salinities in the ore fluids. Stable isotope studies indicate that the ore fluids were enriched in ^{18}O ($\delta^{18}O_{fluid}$ = 6-10‰). The δD values of the ore fluids are strongly depleted in D and latitudinally dependent, indicating the involvement of evolved meteoric water in the ore-forming fluid.

A model for the origin of the mesothermal lode Au deposits in the Canadian Cordillera invokes deep convection (12-15 km) and chemical evolution of meteoric water in the brittle crust. The fluids ascend in highly permeable zones associated with major strike-slip faults. At ~10 km depth, Au-bearing quartz veins are formed. At shallower levels, Sb and Hg deposits are formed. (From authors' abstract by E.R.)

NESBITT, B.E. and MUEHLENBACHS, K., 1989c, Origins and movement of fluids during deformation and metamorphism in the Canadian Cordillera: Science, v. 245, p. 733-736. Authors at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3.

Stable isotope data from quartz veins in the Canadian Cordillera indicate that crustal fluids were heterogeneous in terms of sources and flow paths during Mesozoic-Cenozoic metamorphism and deformation. In regions of strike-slip and extensional faulting, the fluid regime to depths of at least 15 km was dominated by convected, chemically evolved meteoric water. In contrast, in thrust faulted regions, the fluid regime was dominated by fluids derived from metamorphic devolatilization reactions. Deep convection of meteoric water implies that fluid P are hydrostatic in such systems not lithostatic, as had been commonly assumed. The occurrence of significantly lower fluid P would necessitate reevaluation of the manner in which metamorphic phase equilibria and stress relations in the crust are modeled. In addition, this study indicates that mesothermal Au deposits in the Canadian Cordillera are a product of the meteoric water convection process. (Authors' abstract)

NESBITT, B.E., MUEHLENBACHS, Karlis and MUROWCHICK, J.B., 1989, Genetic implications of stable isotope characteristics of mesothermal Au deposits and related Sb and Hg deposits in the Canadian Cordillera: Econ. Geol., v. 84, p. 1489-1506. Authors at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

The Canadian Cordillera hosts a large number of mesothermal, Au ± Ag vein deposits. The deposits are scattered throughout accreted and suspect terranes of the cordillera and often have a distinct spatial association with strike-slip faults. These vein deposits possess a striking degree of homogeneity in $\delta^{18}O$ values on vein, district, and regional scales. In most districts, $\delta^{18}O$ mineralized quartz veins vary only by 2 to 3‰ across the entire district. Over the Canadian Cordillera as a whole, $\delta^{18}O$ values for such veins range from 13 to 18‰ (SMOW). In contrast to the high degree of homogeneity evident in the $\delta^{18}O$ values of the veins, alteration zones in adjoining wall rocks possess distinctive zoning patterns, indicating isotopic exchange between ore fluids and host units.

Deposits of Hg and Sb are also closely associated with strike-slip faults in the Canadian Cordillera area. The $\delta^{18}O$ studies of quartz from these deposits indicate average values of 29 ± 2.0‰ (SMOW) for quartz from the Hg deposits and 21.0 ± 1.5‰ for quartz from the Sb deposits. When corrected for isotopic fractionation assuming equilibrium conditions, average $\delta^{18}O$ values for ore-forming fluids of the various deposit types all fall within a 5‰ range, indicating a probably common fluid source for the three deposit types. All three deposit types have $\delta^{13}C$ values for carbonates in the range of -10 to +2‰ (PDB), which are believed to reflect a heterogeneous source for the carbon. The δD values from serpentinites associated with Au deposits and inclusion fluids from all three deposit types are lighter than -100‰ and latitudinally dependent, indicating the involvement of chemically evolved, meteoric water in the ore-forming process.

A model for formation of these deposits is presented involving the convection of meteoric water in the brittle crust to depths of 12 to 15 km and 300° to 400°C. During descent, the fluid evolves in $\delta^{18}O$ and acquires constituents involved in the later ore-forming process. Fluids ascend in highly permeable zones associated with strike-slip faults, depositing quartz, sulfides, and Au at a depth of ~10 km and 300° ± 50°C. At shallower levels and cooler T, Sb quartz ± Au veins are formed and near the surface, cinnabar and carbonate are deposited at ~150°C. Similarities in geology and geochemistry of mesothermal Au deposits of the Canadian Cordillera and deposits of the Mother Lode, California, and the Archean cratons suggest that the model proposed herein may also be applicable to those deposits. (Authors' abstract)

NEUSER, R.D., RICHTER, D.K. and VOLLBRECHT, Axel, 1989, Natural quartz with brown/violet cathodoluminescence—Genetic aspects evident from spectral analysis: Zbl. Geol. Paläont. Part I, 1988, no. 7/8, p. 919-930 (pub. 1989).

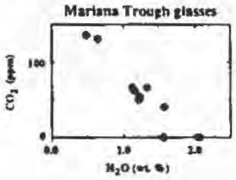
NEWBERRY, R.J., and SCHMIDT, J.M., 1989, Gold contents of zinc-copper-(lead) volcanogenic massive sulfide deposits (VMSD) correlated with oxidation/pH conditions of formation (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A294.

NEWMAN, S., 1989, Water and carbon dioxide contents in basaltic glasses from the Mariana Trough (abst.): Eos, v. 70, p. 1387. Author at Div. Geological and Planetary Sciences, California Inst. Technology, Pasadena, CA 91125.

H_2O and CO_2 concentrations and speciation have been determined by infrared spectroscopy in glasses collected by the submersible ALVIN from 3450-4150 m depth in the Mariana Trough. H_2O contents range from 0.5-2.1 wt %, and CO_2 contents are up to 150 ppm. For H_2O, the species observed in these glasses are OH groups and molecular H_2O, with molecular H_2O/OH increasing with increasing total H_2O content. The only CO_2-bearing species found is $CO_3^=$; molecular CO_2 is absent. As has been previously observed (e.g., Garcia et al., 1979, GCA 43, 305; Poreda, 1985, EPSL 73, 244), H_2O contents of these back arc basin basalts (BABBs) are significantly higher than in mid-ocean ridge basalts (MORBs). CO_2 contents, however, are often higher in MORB than in these BABBs (Dixon et al., 1988, EPSL 90, 87). The most striking feature of the Mariana Trough BABB data is the inverse correlation between dissolved CO_2 and H_2O contents (see figure). There is also an inverse correlation between H_2O content and depth. Calculations using existing solubility data suggest that the melts from which these glasses quenched were saturated with mixed H_2O-CO_2 vapors at their depths of eruption. MORBs are also typically vapor-saturated (or even supersaturated) at eruption, but the vapor is nearly pure CO_2.

The inverse relationship between H_2O and CO_2 contents is similar to that observed for melt inclusions in quartz phenocrysts from the Bishop Tuff. In the Bishop Tuff this trend was interpreted as resulting from closed system crystallization of anhydrous, non-CO_2-bearing phases under vapor-saturated conditions (Anderson et al., 1989, Geol. 17, 221). During this process the residual liquid becomes richer in water and poor in CO_2 as the amounts of vapor and crystals both increase. The important role played by crystallization in generating the compositional variations observed in this suite of basalts is supported by the observed positive correlations for K_2O-SiO_2 and FeO*/MgO-SiO_2 and negative correlations for MgO-SiO_2 and CaO-SiO_2 (J. Hawkins, pers. comm.).

I propose that vapor-saturated crystallization is an important process during high level petrogenesis of the Mariana Trough BABBs. The least fractionated glasses, with the lowest H_2O content, are in equilibrium with a vapor that contains >-90% CO_2, whereas the most fractionated samples are in equilibrium with vapor containing >-90% H_2O. (Author's abstract)



NEWMAN, Sally and CHESNER, Craig, 1989, Volatile compositions of glass inclusions from the 75 Ka Toba Tuff, Sumatra (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A271. First author at Div. of Geological and Planetary Sciences 170-25, California Inst. Technology, Pasadena, CA 91125.

Glass inclusions in phenocrysts from volcanic eruptions hold clues to the pre-eruptive melt composition. We have studied dissolved H_2O and CO_2 contents in glass inclusions from non-welded samples of the youngest Toba Tuff. This tuff is compositionally zoned from rhyolite (76% SiO_2, 710°C) to quartz latite (68% SiO_2, 765°C). Melt inclusion analyses were performed by infrared spectroscopy on doubly-polished inclusions in quartz phenocrysts. H_2O contents range from 5.2 to 5.7 wt %, significantly >4 wt % reported by Beddoe-Stephens et al. (1983, Contrib. Mineral. Petrol., 83, 278-287). CO_2 concentrations are $\leq$~100 ppm. The P indicated by these volatile contents, assuming vapor saturation, are 1500-1850 bars, suggesting depths of 5-6 km. These P are lower than the 3000 to 4000 bars indicated by mineral equilibria. The relative proportions of molecular H_2O and hydroxyl groups, which are known to be T-dependent, indicate T of equilibration of ~500°C (Stolper, unpublished) probably reflecting post-eruption cooling history. Thus, consistent with the non-welded nature of these samples, the Toba Tuff presumably cooled quickly, so that the H-bearing species were not able to re-equilibrate as the glass cooled below 500°C. The volatile compositions of these inclusions are similar to those of the Plinian deposit of the Bishop Tuff, although the Mono Lobe ash flow inclusions contained more CO_2 and less H_2O (Anderson et al., 1989, Geology, 17, 221-225).

Toba inclusions have similar CO_2 contents but lower H_2O contents that rhyodacitic inclusions in plagioclase from the Mount Mazama caldera-forming eruption, Crater Lake, Oregon (Bacon et al., 1988, Geol. Soc. Am., Abst. with Programs, 20, A248). (Authors' abstract)

NEWTON, R.C., 1989, Metamorphic fluids in the deep crust: Ann. Rev. Earth Planet. Sci., v. 17, p. 385-412.

Reviews the state of knowledge on deep crustal metamorphic fluids with emphasis on granulite terrains. (E.R.)

NGUYEN, P.T., BOOTH, S.A., BOTH, R.A. and JAMES, P.R., 1989, The White Devil gold deposit, Tennant Creek, Northern Territory, Australia, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: Econ. Geol. Monograph 6, The Perspective in 1988: The Economic Geol. Publ. Co., p. 180-192. First author at Kambalda Nickel Operations, Kambalda, W. Australia 6442, Australia.

The White Devil Au mine is 33 km northwest of Tennant Creek, in the Northern Territory, Australia. Production began in August 1987, and as of 30 June 1988 the measured and indicated resource totaled 343,000 metric tons at 20.6 g/metric ton Au, with a further 73,000 metric tons having been mined to that date. The full extent of the deposit is yet to be defined. Well-bedded siliciclastic sedimentary rocks of the lower Proterozoic Warramunga Group, which host the mineralization, have undergone two main deformations. The late semiductile to brittle deformation was a progressive deformation, which was associated with at least three closely spaced events, that is, the intrusion of a set of quartz-feldspar porphyry dikes, an early east-west shearing associated with the emplacement of hydrothermal magnetite-rich bodies (ironstones), and a progressive shearing associated with the mineralization.

Textural relationships of the minerals and studies on FI in quartz demonstrate that there were two distinct phases of hydrothermal fluid involved in the formation of the deposit. Magnetite was formed from a fluid of relatively high T (~350°C) and high salinity (probably $CaCl_2$-NaCl), whereas later Au-Bi-Cu mineralization was formed from a fluid of lower T (~300°C) and lower salinity. The origin of the solutions is uncertain, but a preliminary sulfur isotope study suggests a magmatic source for the sulfur. The close association of the ore and magnetite suggests that the magnetite was an important factor in controlling ore deposition. (From authors' abstract by H.E.B.)

NIGHSWANDER, J.A., KALOGERAKIS, Nicolas and MEHROTRA, A.K., 1989, Solubilities of carbon dioxide in water and 1 wt % NaCl solution at pressures up to 10 MPa and temperatures from 80 to 200°C: J. Chem. Eng. Data, v. 34, p. 355-360.

NORDLIE, B.E., PETERSHAGEN, J.H. and DODEN, A.G., 1989, Experimental nucleation and growth of bubbles in a synthetic granitic melt (abst.): Eos, v. 70, p. 502. Authors at Geol. Sci., Iowa State Univ., Ames, IA 50011.

H_2O bubbles were grown in an Ab-Or-Qtz, water-saturated melt. After bubble-free saturation at 800°C and 1 kb, P was decreased (T = const) rapidly (seconds) to 900, 700 or 500 bars to nucleate the bubble phase. Bubbles were then grown over varying times. Melts were quenched (<10 sec) at the final P. Preliminary work included determinations of H_2O saturation (1-1500 bars) and densities of saturated, bubble-free glasses; subsequent bubble growth experiments served as reversals.

Samples were statistically examined for bubble sizes and numbers, and densities were measured. Sizes (diameter) versus frequency are well represented by Gaussian distribution curves; mean size increases with time and bubble growth is completed within 2 hrs. During growth size range increases; smaller bubbles cease to grow, while the largest and mean sizes grow to maxima, e.g., at 700 bars final mean size is .050 mm and sizes range from .01 to .09 mm. Nucleation is completed within about 30 seconds, after which total population is nearly constant. Calculations of densities, based upon glass solubility/density values and total bubble volumes, agree well with measured densities of bubble-containing samples.

Modelling shows that the parabolic growth law holds for part of the process, but not for early and late growth. A more comprehensive model, including interference, is being developed. Derivation of the H_2O diffusion coefficient during the parabolic stage gives 10^{-7} to 10^{-8} cm^2/sec. (Authors' abstract)

NORDSTROM, D.K., BALL, J.W., DONAHOE, R.J. and **WHITTEMORE, Donald**, 1989, Groundwater chemistry and water-rock interactions at Stripa: Geochim. Cosmochim. Acta, v. 53, p. 1727-1740. First author at U.S. Geological Survey, MS420, 345 Middlefield Road, Menlo Park, CA 94025.

Leakage of fluid inclusions may be involved (see next item). (E.R.)

NORDSTROM, D.K., LINDBLOM, Sten, DONAHOE, R.J. and **BARTON, C.C.**, 1989, Fluid inclusions in the Stripa granite and their possible influence on the groundwater chemistry: Geochim. Cosmochim. Acta, v. 53, p. 1741-1755. First author at U.S. Geol. Surv., 345 Middlefield Rd., Menlo Park, CA 94025.

Fluid inclusions in quartz and calcite of the Proterozoic Stripa granite, central Sweden, demonstrate that the rock and its fracture fillings have a complex evolutionary history. The majority of inclusions indicate formation during a hydrothermal stage following emplacement of the Stripa pluton. Total salinities of quartz inclusions range from 0-18 eq. wt % NaCl for unfractured rock and from 0-10 eq. wt % for fractured rock. Vein calcites contain up to 100-150°C for unfractured rock and 100-250°C for fractured rock. P corrections, assuming immediate post-emplacement conditions of 2 kbar, give T ~160°C higher.

Measurements of fluid-inclusion population-densities in quartz range from about 10^8 inclusions/cm^3 in grain quartz to 10^9 inclusions/cm^3 in vein quartz. Residual porosity from inclusion densities has been estimated to be at least 1% which is two orders of magnitude greater than the flow porosity.

Breakage and leaching of fluid inclusions is proposed as an hypothesis for the origin of major solutes (Na-Ca-Cl) in the groundwater. Evidence for the hypothesis is based on (1) mass balance—only a small fraction of the inclusions need to leak to account for salt concentrations in the groundwater, (2) chemical signatures—Br/Cl ratios of fluid inclusions leachates (0.0101) match those ratios for the deep groundwaters (0.0107), (3) leakage mechanisms—micro-stresses from isostatic rebound or mining activities acting on irregular-shaped inclusions could cause breakage and provide connection with the flow porosity, and (4) experimental studies—water forced through low permeability granites leach significant quantities of salt. This hypothesis is consistent with the available data although alternate hypotheses cannot be excluded. (Authors' abstract)

NORDSTROM, D.K., OLSSON, Tommy, CARLSSON, Leif and **FRITZ, Peter**, 1989, Introduction to the hydrogeochemical investigations within the International Stripa Project: Geochim. Cosmochim. Acta, v. 53, p. 1717-1726. First author at U.S. Geol. Surv., 345 Middlefield Rd., Menlo Park, CA 94025.

This is an introduction to a special section of the journal containing 12 papers on Stripa, including discussion on the influence of fluid inclusions. Such papers are individually abstracted here. (E.R.)

NORMAN, D.I., KYLE, P.R. and **BARON, Charles**, 1989, Analysis of trace element including rare earth elements in fluid inclusion liquids: Econ. Geol., v. 84, p. 162-166. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

This study indicates that the methods reported can yield repeatable and reasonable analyses of trace elements in FI liquids and should have broad application to the study of FI fluids in ore deposits and metamorphic rock. These initial analyses have measured a number of elements heretofore not determined in inclusion fluids, some, such as Ag, Ce, and light rare earth elements, in remarkably high concentrations. A broad spectrum of elements is indicated to be mobile in hydrothermal brines, and the indicated distribution of elements presents a picture of Copper Flat [porphyry Cu deposit] hydrothermal brines as mobilizing elements in each of Goldschmidt's (1954) classes to roughly the same degree. (From authors' text by E.R.)

The 30 elements analyzed are: Na, K, Sc, Cr, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Mo, Ag, Sb, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, W, Au, Th, and U. (E.R.)

NORMAN, D., WAN, J. and MUSGRAVE, J., 1989, Measurement of oxygen and sulfur fugacity in epithermal fluids (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 48. Authors at Dept. Geosci., New Mexico Tech., Socorro, NM 87801.

Oxygen and sulfur fugacity of geothermal fluids are calculated from analyses of inclusion volatiles by bulk analysis that allows accurate measurement of ppb levels of gases. H_2S is absorbed onto fresh surfaces when inclusions are opened by crushing, hence H_2S is best measured by opening inclusions by thermal decrepitation. However, heating above Tt results in a reequilibration of the inclusion volatiles to produce more H_2 and CO_2 than in the trapped fluid. The reaction (1) $CH_4 + 2H_2O = CO_2 + 4H_2$ goes to the right with increasing T. One need not measure gases both by crushing and thermal decrepitation in order to get an accurate measurement of the gaseous species for calculation of $f(S_2)$ and $f(O_2)$. The original composition of the inclusion volatiles released by heating can be calculated by treating the eq. 1 as a geothermometer.

(2) $T = \log((f(H_2)^4 * f(CO_2))/(f(H_2O)^2 * f(CH_4))) + K$

The procedure is to subtract CO_2 and H_2 in the ratio of 4:1 and add CH_4 and H_2O in the ratio 1:2 to the analysis until the geothermometer indicates the Tt (determined by microthermometry). This procedure yields virtually identical values as obtained by crushing the sample.

Oxygen fugacity is calculated from five equations: (3) $H_2O = H_2 + 1/2O_2$; (4) $CH_4 + O_2 = CO_2 + 2H_2$; (5) $CH_4 + 2O_2 = CO_2 + 2H_2O$; (6) $C + O_2 = CO_2$; (7) $C + 2H_2O = CH_4 + O_2$.

Generally log $f(O_2)$ values calculated for equations 3, 4, and 5 agree within 0.2 log units. For most epithermal deposits (e.g., Carlin, Guanajuato, Creede), log $f(O_2)$ values calculated from eqs. 3-7 closely agree indicating the ore solutions were buffered by carbon. Generally there is other evidence why this should be true in that the country rock is carbonaceous, or inclusions contain organic compounds other than CH_4. Fewer deposits indicate ore solutions were somewhat more reduced. For these, $f(O_2)$ was apparently buffered by po-py similar to the Broadlands, NZ, geothermal system.

Sulfur fugacity is calculated from: (8) $2H_2S + O_2 = S_2 + 2H_2O$. Typical calculated log $f(S_2)$ values for 250°C fluids are -8 to 16. (Authors' abstract)

NOSIK, L.P., KUCHER, M.I. and NOSIK, V.L., 1988, Isotope effects-indicators of the boiling processes of hydrothermal solutions: Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 49-50 (in Russian). First author at IGEM Acad. Sci., Moscow, U.S.S.R.

The boiling processes of hydrothermal solutions influence isotope equilibria. This is shown by the example of carbon-bearing species in "defects" (type not specified) of the quartz lattice of a gold deposit. (A.K.)

Quartz generation	Gold content*	pV CO_2 cm^3/g quartz	$\delta^{13}C$, ‰		T, °C	L, %	Formation conditions
			CO_2	C			
I	0.1-10.0	0.02-4.85	-7.5	-24.8	220	74	red.
II	0.0-1.0	0.16-58.14	-4.0	-14.2	240	97	oxid.
III	0.7-30.7	0.28-12.14	+8.4	-26.0	217	60	red.
IV	0.0	1.02-28.57	-1.5	-13.2	150	98	oxid.

NOVOTNY, M.V., 1989, Recent developments in analytical chromatography: Science, v. 246, p. 51-57. Author is the Rudy Professor of Chemistry, Indiana Univ., Bloomington, IN 47405.

Capillary gas chromatography (GC) is rapidly reaching a state of maturity. Recent advances in GC include new highly selective and stable open-tubular columns, capillary sampling techniques, and element-sensitive (plasma) detectors. An impressive growth of modern liquid chromatography continues with an emphasis on the separation of biopolymers, new silica-based and stable polymeric packings, microcolumn techniques, electroosmotically driven separations, and ultrasensitive detection. Supercritical fluid chromatography has gained considerable attention primarily because of its distinctive detection capabilities. Novel combinations of chromatographic techniques with each other, or with spectroscopic methods, continue to be explored. (Author's abstract)

OAKES, C.S., 1988, Evidence for replacement of dilute hydrothermal solutions by hot, hypersaline brine in the northeastern part of the Salton Sea geothermal system, California: A fluid inclusion and oxygen isotope study: M.S. thesis, Univ. California, Riverside, CA, 115 pp.

The Salton Sea Geothermal System (SSGS) is a high-T hypersaline geothermal system on the delta of the Colorado River developed in Tertiary to Holocene sedimentary rocks. This thesis studied samples from the Fee #1, Fee #5, and Britz #3 geothermal wells in the northeastern part of the SSGS, which produce Na-Ca-K-Cl brines containing from 117,000 to 253,000 ppm total dissolved solids (TDS).

Fluid inclusion Th from vein calcite and quartz cuttings are in close agreement with T logs and indicate maximum reservoir T between 290° and 310°C at 3140 to 3565 m for these wells. Tm ice of fluid inclusions imply the trapping of both "low" salinity (10,000-100,000 ppm NaCl eq.) and high salinity solutions in vein minerals. Moderate to high salinity inclusion fluids appear similar to the produced reservoir fluids in TDS, while both high salinity and low salinity inclusions imply paleo-reservoir T similar to those measured by T logs.

The occurrence of low salinity fluid inclusions in production horizons which now produce high salinity brines implies that the saline brines have displaced more dilute fluids. Fluid inclusions within vein minerals from the Britz #3 well that have higher salinities than the production brine, however, indicate that the converse has also occurred. Replacement of low salinity brines by high salinity brines has apparently occurred only at depths where reservoir T has been ≥270°C.

$\delta^{18}O$ compositions of brines calculated to be in equilibrium with calcite and quartz veins imply that the veins were deposited from three isotopically distinct brines characterized by $\delta^{18}O$ values of -4‰ to -2‰, ~-1‰, and +1‰ to +3‰. The low range of compositions appears to correspond to low salinity brines that were present at reservoir T of 240°-310°C. Veins implying the heavy range of compositions were apparently precipitated from high salinity brines at T > 270°C. The process responsible for producing a brine with an extremely limited intermediate $\delta^{18}O$ composition is enigmatic. The $\delta^{18}O$ value of the latter brine may be characteristic of: high salinity brines in regions of the reservoir where water/rock ratios are high; high salinity brines that are relatively new to the regions of the reservoir where they are found; or a process in which calcite saturation and the $\delta^{18}O$ composition of the precipitating brine are associated with diffusional or eddy mixing at the interface between high TDS, high $\delta^{18}O$ and low TDS, low $\delta^{18}O$ endmembers. (Author's abstract)

OAKES, C.S., BODNAR, R.J. and SIMONSON, J.M., 1989, P-V-T-X properties in the system $NaCl-CaCl_2-H_2O$ at low temperatures (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 49. First author at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

Densities and freezing point depressions [Tm ice] have been measured for the range of $NaCl-CaCl_2-H_2O$ solution compositions spanned by the ice stable field. Densities were measured with a vibrating U-tube densimeter at 25° and 35°C and 1 atm for NaCl/(NaCl + $CaCl_2$) weight fractions (X) of 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0. The 25°C density data are in excellent agreement with previously published data along both binaries. The 35°C data for the $NaCl-H_2O$ binary are widely scattered. Our data are in good agreement with one of these published data sets and with the empirical fitting equation produced by Monnin (1987, J. Soln. Chem., 16, 1035). Densities for ternary solutions are available only at 25° and 35°C and have been measured by us and one other research group. Agreement between the two data sets is poor; however, we believe our data to be superior due to the apparently greater accuracy of our data along the binaries.

Our 25°C density data were used to construct a calibration equation for wt % total salt expressed as a function of density and X. Total salt concentrations for the freezing point depression solutions were determined by substituting their densities (at 25°C) into the calibration equation. The total salt concentrations were then fit to an equation as a function of freezing point depression T and X. Freezing points were determined for concentrations between 3 wt % total salt and the cotectic boundaries of the ice stable field. The results are in excellent agreement with published data along the $NaCl-H_2O$ binary but show large discrepancies with previous determinations of the ice liquidus along the $CaCl_2-H_2O$ binary and in $NaCl-CaCl_2-H_2O$ ternary. Te and compositions were found to be -21.19°C (±0.01°) and 23.2 wt % for the $NaCl-H_2O$ binary and -51.0°C (±0.5°) and 30.6 wt % for the $CaCl_2-H_2O$ binary. The maximum freezing point depression [Tm ice] reached during our experiments in the ternary system was -37°C, therefore we do not report isotherms below -35°C or a T for the ternary eutectic. At moderate to high salinities isotherms cross the ice sub-field at lower total salt concentrations than previously reported. Our results indicate that total salt concentrations determined from Tm hydrohalite ice in FI and previously published freezing point data cause errors as large as 2 wt %. Similarly, NaCl/($CaCl_2$ + NaCl) weight fractions estimated from previously published data may be in error by as much as X = 0.15. (Authors' abstract)

ODOM, A.L. and **RINK, W.J.**, 1989, Giant radiation-induced color halos in quartz: Solution to a riddle: Science, 4. 246, p. 107-109. Authors at Dept. Geology, Florida State Univ., Tallahassee, FL 32306.

The radii of radiation-induced color halos (RICHs) surrounding radioactive mineral inclusions in mica generally correspond closely to the calculated range of common uranogenic and thorogenic alpha particles in mica. Many exceptions are known, however, and these variants have led investigators to some rather exotic interpretations. Three RICHs found in quartz are identified as aluminum hole-trapping centers. Whereas the inner radii of these RICHs closely match the predicted range of the most energetic common alphas (30 micrometers), the color centers observed extend to 100 micrometers. Migration of valence-band holes down a radiation-induced charge potential might account for enigmatic RICHs. RICHs provide natural experiments in ultraslow charge diffusion. (Authors' abstract)

O'GRADY, M.R., BODNAR, R.J., HELLGETH, J.W., CONROY, C.M., TAYLOR, L.T. and **KNIGHT, C.L.**, 1989, Fourier-transform infrared (FTIR) microspectrometry of individual petroleum fluid inclusions in geological samples, *in* P.E. Russell (ed.), Microbeam Analysis-1989, San Francisco Press, San Francisco, CA.

See next item. (E.R.)

O'GRADY, M.R., HELLGETH, J.W., CONROY, C., TAYLOR, L.T. and **BODNAR, R.J.**, 1989, Fourier transform infrared microprobe (FTIRM) analysis of petroleum fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 50. First author at Dept. Chem., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061-0212.

In recent years, the use of FI techniques to study mineral diagenesis and petroleum generation and migration in sedimentary basins has become common. P aqueous FI in overgrowths on detrital grains, in cements in clastic rocks, and in fracture-filling minerals provide valuable information on the P-T conditions of mineral formation, as well as compositions of diagenetic fluid(s). The presence of petroleum inclusions provides definitive evidence that oil has migrated through the rock at some time, and by relating the paragenesis of the oil inclusions to other structural and chemical features, the timing of oil migration relative to these events may be determined. The use of FI to reconstruct the physical and chemical environment of petroleum generation and migration is limited by our ability to accurately determine the composition of the petroleum contained in inclusions. We have initiated a research program to develop Fourier Transform Infrared Microprobe (FTIRM) techniques to analyze individual petroleum FI in various host minerals. The most suitable host minerals tested, in terms of their transparency over the range of interest (~700 to 4000 cm^{-1}) are halite > fluorite > calcite ≈ quartz.

Figure 1

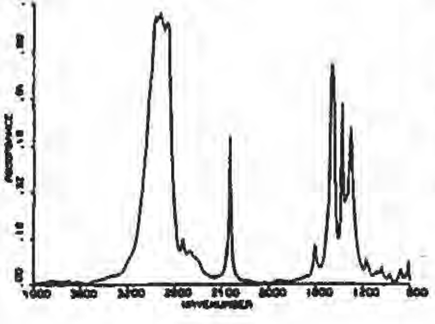
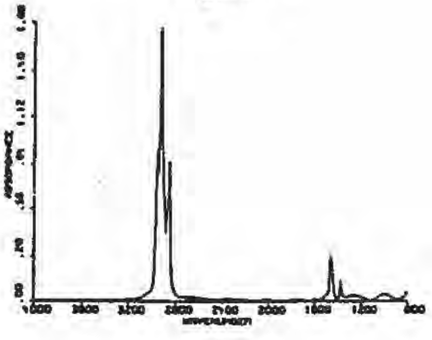


Figure 2



Spectra obtained from a petroleum inclusion contained in halite from a producing oil well in the Gulf of Mexico were compared with spectra obtained on bulk oil samples produced from the same well. The inclusion contains two distinct phases—a brown-orange liquid petroleum phase that fluoresesces bright yellow under UV illumination and a dark vapor phase. The inclusion spectrum shows a strong, broad absorption band in the C-H stretch region with peaks at 2856, 2922 and 2961 cm^{-1} (Fig. 1). These correspond to symmetric methylene, asymmetric methylene, and asymmetric methyl stretches, respectively. The shoulder above 3000 cm^{-1} corresponds to an aromatic C-H stretching frequency. Absorptions in the fingerprint region support these assignments. The strong, sharp band at ≈2337 cm^{-1} is due to CO_2, either under high P or dissolved in the petroleum phase, or both.

The spectrum obtained from the bulk oil sample (Fig. 2) shows several obvious differences. Absorption bands at 2337 and 1300 cm^{-1} are absent in the bulk oil spectrum—these correspond to CO_2 as described above, and to CH_4, respectively. The absence of absorbances above 3000 cm^{-1} reflects the lack of aromatic components; this is supported by the fact that the bulk oil sample does not fluoresce under UV illumination. These differences suggest loss of the more volatile components CO_2, CH_4 and aromatics during sampling. (Authors' abstract)

OHBA, T. and **KAZAHAYA, K.,** 1989, Cooling rate of hydrothermal quartz: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 529-532. First author at Kusatsu-Shirane Volcano Observatory, Tokyo Institute of Technology, Gunma, Japan.

A correlation was found between the oxygen isotope ratio of inclusion water in a hydrothermal quartz and the radius of fluid inclusion. The $\delta^{18}O$ value of inclusion water with radius 15 μm was 11‰ higher than that with radius 5 μm, and was neither equilibrated with the $\delta^{18}O$ value of host quartz at the Tf of quartz nor at the present T of mine. The correlation and the deviation from the equilibrium can be explained by a model based on ^{18}O diffusion in the quartz crystal. As an application of the diffusion model, cooling rate was estimated for the hydrothermal quartz. (Authors' abstract)

OHYAMA, Y. and **SHIMADA, N.,** 1989, Genetic relationships between lead-zinc ore deposits and the Uchiyama granitic body, Tsushima—(2) Fluid inclusion study (abst.): Min. Geol., v. 39, p. 55 (in Japanese, translated by S. Taguchi). Authors at Fac. of Sci., Kyushu Univ.

Pb-Zn vein type deposits occur in Paleogene sediments on Tsushima Island, Kyushu, Japan. The mineralization appears to be related to the Uchiyama granitic rocks (12-16 Ma), which are exposed widely in the southern part of the island, showing a zonal arrangement of magnetic susceptibility.

Fluid inclusions of quartz from the granite are usually three-phase inclusions with halite, and sometimes also opaque minerals. Th ranges from 320-530°C, and salinities are 37-61 eq. wt % NaCl. There is no relation between the magnetic susceptibility and Th or salinity.

In contrast, fluid inclusions from pyrrhotite-quartz veins of the Ohfunakoshi deposit are all two-phase inclusions, with Th of 230-380°C and 2.4-7.5 eq. wt % NaCl.

These results indicate that the ore solution migrated from the granite to the Paleogene sediments and mixed with meteoric water in the sediments, resulting in dilution, T decrease, and finally ore precipitation. (Authors' abstract)

OLADE, M.A. and **OGUNDIPE, I.O.,** 1989, Stable isotope geochemistry and origin of riftogenic lead-zinc-barite deposits, Benue Trough, Nigeria (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-544.

OLDFIELD, Gordon, 1989, Gladstone Hill epithermal system, Waihi, N.Z., *in* P.R.L. Browne and K. Nicholson (eds.), Proc. 11th New Zealand Geothermal Workshop: Geothermal Inst., Univ. Auckland, p. 195-200. Author at Epithermal Mineralisation Research Unit, Geology Dept., Univ. Auckland, Private Bag, Auckland, New Zealand.

The small Gladstone Hill epithermal vein system is hosted by hydrothermally altered pyroxene andesites of Miocene age. The alteration is characterised by a propylitic assemblage which increases in intensity towards veins which comprise quartz-adularia. Fluid inclusion data obtained on surface samples and shallow cores indicate depositing fluids were of low apparent (NaCl eq.) salinity at T that reached 250°C in deeper sections of the area (350 m below the top of Gladstone Hill), dropping to below 180°C in the shallowest rocks. The top of Gladstone Hill was then 2-300 m below the water table. Late deposited calcite and acid-sulphate produced mineral assemblages, the latter being particularly associated with a brecciated zone. Both assemblages are probably related to the collapse of the geothermal system responsible for the mineralisation. (Author's abstract)

ORESKES, Naomi and EINAUDI, M.T., 1989, Origin of Proterozoic Fe (Cu-U-Au-REE) deposits: Evidence from Olympic Dam, South Australia (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A33. Authors at Geology Dept., Stanford Univ., Stanford, CA 94305.

Proterozoic Fe (Cu, U, Au, Ag, REE) deposits within granitic terrains, such as occur in SE Missouri, U.S.A., Kiruna, Sweden, and Olympic Dam, South Australia, have been the subject of considerable controversy. Genetic hypotheses range from hydrothermal replacement to injection of Fe oxide magmas. At Olympic Dam, detailed mapping and petrographic studies indicate that hematite breccias formed by intense brecciation and Fe-metasomatism of wall-rock granite in a near-surface hydrothermal environment. Rare earth minerals are intergrown with hematite and their distribution indicates that REEs were introduced by hydrothermal fluids. Although felsic dikes cut the breccias, and locally are themselves brecciated, fluid inclusion and stable isotope data suggest that hydrothermal fluids were not of direct magmatic derivation.

S L+V inclusions in granitic quartz fragments within the breccias display a broad range of Th of ~140-360°C. The highest Th are found in detrital quartz grains within clasts of sedimentary barite in hematite breccia. Inclusions in quartz fragments from the matrix of the same breccias display lower Th, mainly 160-210°C. The latter display a wide range of [Tm ice?], and commonly form clathrates and metastable solids upon freezing. Rare inclusions are halite-saturated, and some contain trapped hematite crystals. P L+V inclusions from fluorite veins that cut the breccias have Th = 90-150°C, also form clathrates, but none is halite saturated. Preliminary $\delta^{18}O$ values of hematite from the breccias range from -1 to -12‰ (eight samples). Minor magnetite in the deposit contains distinctly different $\delta^{18}O$ ranging from 0 to +3‰ (five samples). Although the magnetite isotopic data suggest that early hydrothermal fluids may have been equilibrated with igneous basement, the bulk of the data from Olympic Dam indicates moderate T, variable salinity, CO_2-bearing hydrothermal fluids of dominantly meteoric origin. REEs were concentrated by hydrothermal processes with no evidence of a direct magmatic input within the exposed portions of the deposit. This contrasts with interpretations of Proterozoic Fe deposits elsewhere, in which REEs have been cited as evidence of elemental partitioning into immiscible Fe oxide magmas. (Authors' abstract)

ORTEGA, L., VINDEL, E. and BENY, C., 1989, C-O-H-N fluid inclusions associated with gold-stibnite mineralization in low-grade metamorphic rocks, Mari Rosa mine, Caceres, Spain (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 72. First author at Fac. de Ciencias Geol., UCM, 28040 Madrid, Spain.

Mari Rosa mine lies within low-grade Precambrian terrain in the Spanish Hercynian Massif, which comprises an alternating series of black shales and metagreywackes. There are two generations of mineralized veins: V2, Au (stibnite)-bearing quartz veins, concordant with the main cleavage, showing pinch and swell structures; and V3 stibnite-bearing quartz veins which post-date the main deformation.

Based on microscopic, microthermometric and Raman spectrometric studies, four main types of FI have been identified; types I, II and IV are aqueous-carbonaceous FI, with different degrees of filling, while type III is non-aqueous, typically one-phase at room T. Except for type I (absent in V3), similar inclusions have been observed in both V2 and V3 veins. Gas compositions are always made up by CH_4-CO_2-N_2, ranging from CO_2-rich mixtures in the youngest inclusions (type I) to N_2-rich mixtures in the oldest inclusions (type IV). The proportion of CH_4 remains rather constant in this process.

Au deposition in V_2 veins must be related to the FI type I at $T \geq 380°C$ (Th = 320-380°C). A subsequent drop in $P(CO_2)$ is recorded in type II FI, trapped at Th 240-330°C, which may be characteristic of the stibnite main deposition stage in V3. This deposition may mark the transition from a type II fluid to a type III non-aqueous fluid. The type IV FI, which are the richest in H_2O, represent a later, lower T (Th = 190-270°C), fluid circulation in the ore deposit. (Authors' abstract)

ORTEGA, L., VINDEL, E., GUMIEL, P. and BENY, C., 1989, Characterization of fluid inclusions from gold-stibnite bearing quartz veins at the Mari Rosa mine, Caceres, Spain (abst.): Terra abstracts, v. 1, p. 30.

Mari Rosa Mine is in black shales and metagreywackes that show a low-grade metamorphism.

Three types of veins have been established based upon the mineralogy and the structural style: V1, unmineralized quartz veinlets folded by the main Hercynian cleavage; V2, Au-(stibnite)-bearing quartz veins which clearly crosscut the main cleavage. [sic]

Microthermometric and Raman spectroscopy analyses of fluid inclusions in V2 and V3 veins show the presence of type I (N_2)-CO_2-CH_4-H_2O, type 2 N_2-CO_2-CH_4-H_2O, type 3 N_2-CH_4-CO_2, and type 4 N_2-CH_4-H_2O fluid inclusions.

The evolution of the ore-forming fluids, the transport and deposition of Au in the metamorphic environment is discussed in this paper. (From authors' abstract by E.R.)

OSBORN, W.L., 1989, Formation, diagenesis, and metamorphism of sulfate minerals in the Salton Sea geothermal system, California, U.S.A.: MS thesis, Univ. California, Riverside, CA.

The Salton Sea geothermal system, located in the Salton Trough of southern California, offers a unique opportunity to study the formation, diagenesis, and metamorphism of continental evaporites in an active rift environment. This report is based on an investigation of sulfate minerals found in drill cuttings and core from various wells drilled in the Salton Sea geothermal field, especially those recovered from the 3.2 km-deep Salton Sea Scientific Drilling Project well State 2-14.

The Salton Trough is a continental rift zone, forming the transition from the divergent tectonics of the East Pacific Rise to the strike-slip tectonics of the San Andreas Fault system. Infilling of the rift by the bi-polar Colorado River delta for the past 4 Ma has isolated the northern part of the trough, forming the closed Salton Basin in an orographic desert. High evaporation rates combined with an extremely variable hydrologic budget have resulted in the episodic formation of saline lakes and lacustrine evaporites. Rapid subsidence and rift-related intrusions at depth subject the Pleistocene and younger sediments to $T \leq 350°C$ at 2-3 km depth within the Salton Sea geothermal system (SSGS).

Stratiform sulfate structures observed in drill core are produced by deposition in various playa-sabkha subenvironments: laminated to massively bedded sulfates were deposited subaqueously in perennial and ephemeral saline lakes; gypsum (now pseudomorphed by anhydrite) was precipitated within fluid-saturated sediments in lake-fringing saline mudflats; and nodular sulfates were formed in the capillary zone of surrounding dry mudflats.

Gypsum is the only primary evaporitic sulfate found in the SSGS, where it undergoes dehydration to anhydrite at 80-105°C and depths of 200-250 m. Fluid inclusions in gypsum contain 4-12 wt % eq. NaCl fluids. Gypsum dehydration apparently dilutes these fluids, forming inclusions in anhydrite that contain <4 wt % eq. NaCl fluids. Fluid inclusion Th closely parallel the thermal profile measured in boreholes, implying continual recrystallization of anhydrite to maintain thermal equilibrium with the prevailing geothermal gradient. Continuous recrystallization allows heterogeneous mixing of relatively dilute fluids from inclusions with more concentrated geothermal brines, producing inclusions containing fluids ranging from 13-25 wt % eq. NaCl. These coexist spatially with 25 wt % NaCl geothermal brines.

Incomplete replacement of anhydrite by calcite occurs at depths >600 m, and by epidote and/or tremolite at depths >1400 m. These replacement reactions contribute sulfate to the hydrothermal fluids and may be a significant source of sulfur necessary for sulfide mineralization. Similar metamorphic replacement reactions may alter the appearance, and obscure evidence for an evaporite origin, of similar sediments in ancient greenstone belts. (Author's abstract)

OSCARSSON, N., 1989, Origin of volcanic gases in mantle derived magmas of Icelandic rift-zone: Evidence from analysis of fluid inclusions (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-555. Author at Univ. Iceland, Reykjavik, Iceland.

Accretion of the oceanic plate involves the displacement and effusion of both mantle-derived magmas evolved within crustal reservoirs. Chemical composition of fluid inclusions in phenocrysts of mantle-derived basalts and in cumulative phases (nodules) from reservoirs of such magmas reveals a continuous trend in the evolution of dissolved volatiles during ascent and residence in subcrustal and crustal reservoirs. Within the tholeiitic basalt suite of the oceanic rifts, the most primitive rocks are the picrites (oceanites) and low potassium tholeiites. Phenocryst phases of the picrites are olivine (Fo90), chromian spinel, Cr-diopside, and plagioclase (An90), and the rare occurrences of glass within this magma type contain extremely low, if any, ferric iron.

Fluid inclusions in mantle phases (olivine, plagioclase, Cr-diopside) are composed of H, H_2O, CH_4, CO, and N with minor C_2H_6 and CO_2. Graphite is also present in the inclusions. Assuming that graphite is derived from the disproportionation of CH_4 during cooling, according to the reaction: $CH_4(g) = 2H(g) + C(s)$, and that carbon monoxide is formed according to: $C(s) + H_2O(g) = CO(g) + H_2(g)$, the restored fluid composition at magmatic T closely resembles that of a fluid in equilibrium with iron-wüstite-graphite (IW) system at high P and T. The mantle-derived fluid phase, as inferred from thermodynamic calculations and experiments, is dominated by methane with H and H_2O in lesser amount. Minor and trace constituents are CO_2, CO, and C_2H_6 (Jakobsson and Oskarsson, 1988). Due to different solubility of these species in the silicate melt, as inferred from analysis of glass inclusions and experiments (Holloway and Jakobsson, 1986), their abundances in the silicate melt are dominated by H_2O, the carbon oxides, and H. CH_4 is virtually insoluble in the melt such that the mantle-derived magmas are unable to transport the principal carbon species of the mantle fluid.

Mantle-derived magmas residing in reservoirs at the mantle crust boundary beneath the rift-zones evolve into primitive ol-tholeiites that are the dominating plate-forming magmas. Fluid inclusions from cumulate phases of this magma type are clearly formed within the same chemical system as those of the mantle phases. The major difference of the two inclusion families is that C_2H_6 and graphite are not encountered in the cumulate phases. In terms of C-O-H relations, the fluid phase formed at the reservoir-stage (cumulate) is more oxidized than the mantle fluid.

In Figure 1 the H_2-H_2O relations of fluid inclusions in few phenocrysts and cumulate phases from the Icelandic rift-zone are compared. Samples to the left in the figure (samples HEO1 to LPP1) represent inclusions in phenocrysts from picrites and low K tholeiites (mantle derived), but the samples to the right represent inclusions in cumulate phases from olivine tholeiites.

Note that the plot refers to the fluid phase as analyzed and that the samples are drawn in order of increasing total O content and that there is a strong indication that H obeys an inverse relationship to O.

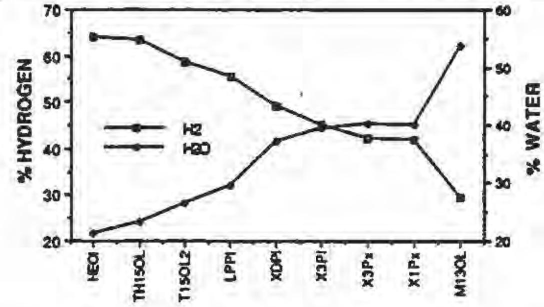
It is evident that fluid inclusions from the cumulate phases represent a second generation of volatiles that have suffered a significant loss of H. In the samples analyzed so far, the composition of these inclusions indicates O fugacity close to that of the magnetite/wüstite (MW) system.

A first basic conclusion from the present data is that the high solubility of H_2O and the carbon oxides in a silicate melt controls the transport of volatiles in ascending mamas, which implies that the transported (dissolved) volatiles are inevitably more oxidized than the volatiles of the mantle source region. Second, a reequilibration of the dissolved volatiles after detachment from the graphite-containing mantle involves oxidation of the silicate melt.

The steady loss of H from magma reservoirs (Sato, 1978) further amplifies the oxidation of the melt, finally leading to the well-documented quartz/magnetite/fayalite (QFM) oxygen buffer system.

Fluid inclusions from late phenocrysts from shallow magma reservoirs (sample M1301) in figure) in the rift-zone and from inclusions to Pélé's hair indicate that the volcanic gases released during an eruption are generally enriched in the more soluble volatiles (H_2O, CO_2) and bear no clear relation to the mantle sources of these magmas. (Authors' abstract)

Figure 1



OSMAN, A. and **PIESTRYZYNSKI, A.**, 1989, Mechanism of sulfide mineralization through successive metasomatic replacement stages of zoned host dolomite in Cracow-Silesian Zn-Pb deposits (Mississippi Valley type), Pomorzany Mine, Poland: Mineral. Deposita, v. 24, p. 56-61.

OUDIN, E., PASCAL, M.-L. and **RAMBOZ, C.**, 1989, Boiling and precious metal deposition in Atlantis II Deep, Red Sea (abst.): Terra abstracts, v. 1, p. 26-27.

Precious metal deposition (Au and Ag) related to boiling hydrothermal solutions have been observed for the first time in Atlantis II Deep sediments. Microthermometric studies of fluids trapped in sulfates show that barite and anhydrite are precipitated by brines (10 % eq. NaCl) mainly between 400°C (where boiling occurs) and 250°C. The reduced brines precipitate sulfides in the upper units and sulfates associated with other sulfides in the upper units through oxidation due to local interaction with the oxidized sediment and loss of hydrogen during boiling. Au probably forms chloride complexes in the high T, acid and highly saline solutions. The Au-barite association suggests that they are present in fluids having a specific chemical composition. Au precipitation may occur during cooling and may be enhanced by the mechanical effect of the boiling process. (From authors' abstract by E.R.)

OZIMA, Minoru, 1989, Gases in diamonds: Ann. Rev. Earth Planet. Sci., v. 17, p. 361-384.

OZIMA, M., ZASHU, S. and **BOYD, S.R.,** 1989, Noble gas isotopic composition in coated diamonds: Representative of the upper and lower mantle? (abst.): 28th Int'l Geol. Congress Workshop on Diamonds, Extended Abstracts, p. 80-82.

OZIMA, M., ZASHU, S., TAKIGAMI, Y. and **TURNER, G.,** 1989, Origin of the anomalous ^{40}Ar-^{39}Ar age of Zaire cubic diamonds: Excess ^{40}Ar in pristine mantle fluids: Nature, v. 337, p. 226-229. First author at Geophys. Inst., Univ. Tokyo, Tokyo 113, Japan.

Cubic diamonds from Zaire show excellent correlations between K content and ^{4}Ar/^{36}Ar ratio, and between ^{40}Ar/^{36}Ar and ^{39}Ar/^{36}Ar, which can be interpreted to yield an 'isochron' age of about 6 Gyr. Now the discovery of a correlation between Cl content and ^{40}Ar, together with recent mineralogical and geochemical work concerning the origin of cubic diamonds, strongly suggests that the ^{40}Ar is an excess component which has no age significance, and that the ^{40}Ar and its associated K are contained in sub-micrometer inclusions of mantle-derived fluid. (Authors' abstract)

PALAIS, J.M. and **SIGURDSSON, Haraldur,** 1989, Petrologic evidence of volatile emissions from major historic and pre-historic volcanic eruptions, *in* A. Berger, R.E. Dickinson and J.W. Kidson (eds.), Understanding Climate Change: AGU Monograph 52, p. 31-53. Authors at Graduate School of Oceanography, Univ. Rhode Island, Kingston, RI 02881.

Estimates of volcanic volatile composition and mass release of S, Cl & F to the atmosphere from twelve large Recent and Quarternary volcanic eruptions has been made on basis of pre-eruption volatile composition, as determined by electron microprobe in glass inclusions trapped in phenocrysts in tephra. These estimates extend our knowledge of atmospheric loading by volcanic gases to include events more than two orders of magnitude larger than recent eruptions observed with modern methods. Results for several events agree well with other independent estimates, based on ice cores and atmospheric studies. The results show that yield of S, Cl and F to the atmosphere is not only dependent on total erupted mass, but largely determined by the composition of the erupting magmas. Thus volcanic volatile yield from high-silica or rhyolitic explosive eruptions is one or two orders of magnitude lower than during eruption of equal mass of basaltic or trachytic magmas. S yield during individual events is up to 3×10^{13} g, such as in the case of the basaltic fissure eruptions of Laki and Eldgja in Iceland. However, in certain trachytic eruptions the yield of halogens may exceed S output, such as during the great 1815 Tambora eruption in Indonesia, when Cl & F yield to the atmosphere is estimated as 2×10^{14} and 1.7×10^{14} g, respectively. Petrologic estimates of S yield correlate closely with northern hemisphere annual T anomalies observed following the eruptions, in agreement with the findings of Devine et al. (1984) on a smaller data base. (Authors' abstract)

Includes 21 complete electron microprobe analyses of glass inclusions and equivalent matrix glasses; each analysis is the average of up to 15 determinations. (E.R.)

PALINKAS, L.A., 1989, Unexpected fluid inclusion composition in barite from the Lika barite deposits: Geol. vjesnik (Zagreb), v. 42, p. 301-310. Author at Mining-Geology-Petroleum Engineering Faculty, University of Zagreb, Pierottijeva 6, 41000 Zagreb, Yugoslavia.

Barite minerals from the Lika ore deposits in the Upper Carboniferous sedimentary rocks with "stratabound" character and still puzzling origin were objects of the fluid inclusion study. The results are not unequivocal, since fluid inclusions are suspected to be S. Peculiar fluid inclusion composition (alkali sulfates, carbonates and bicarbonates) is not in contrary, however, to inclusion composition in barite from the Mississippi Valley type deposits [sic]. Along with epigenetic origin, early and late diagenetic processes cannot be excluded. Less likely is engagement of hydrothermal convective cells, caused by disturbed thermal gradient during early intra-continental rifting in Dinaric realm. (Author's abstract)

PALMER, M.R. and **EDMOND, J.M.**, 1989, Cs/Rb ratio of submarine hydrothermal fluids: Implications for nature of hydrothermal circulation (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-567.

PALMER, M.R., EDMOND, J.M., SLACK, J.F. and **ZIERENBERG, R.A.**, 1989, Boron isotopic studies of modern and ancient submarine hydrothermal systems (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-566.

PAN, Pujing and **SUSAK, N.J.**, 1989, Co(II)-chloride and -bromide complexes in aqueous solutions up to 5 m NaX and 90°C: Spectrophotometric study and geological implications: Geochim. Cosmochim. Acta, v. 53, p. 327-341.

PAN, Vivian and **HOLLOWAY, J.R.**, 1989, Experimental investigation of peridotite-alkali basalt-CO_2 melting relations at 10 kb (abst.): Eos, v. 70, p. 1394. First author at Dept. Geology, Arizona State Univ., Tempe, AZ 85287.

Basalt sandwich experiments were performed to determine the effect of CO_2 in alkali basalt generation. The experiments were designed to extract mineral-melt equilibria, O fugacity, CO_2 solubility and CO_2 speciation. Experiments were conducted at 10 kb with alkali basalt and peridotite from the San Carlos, Arizona volcanic field. Ag oxalate was added to the graphite capsule as the CO_2 source. A Pt wire added to the capsule allowed fO_2 determination (Gudmundsson et al., 1988). CO_2 solubility in the basalt glass was measured using micro-infrared spectroscopy. Volatile-free experiments were also performed to gauge the effects that CO_2 has on melt compositions and melting relations.

Experiments at 1200°C yielded silica-undersaturated liquids coexisting with olivine, orthopyroxene, clinopyroxene and Cr-spinel under CO_2-vapor undersaturated conditions. The CIPW norm (mole %) of the liquid composition is or + ab + an = 51, ne = 12, di = 7, ol = 19, mt = 1.4, il = 8 and ap = 1.3. CO_2 concentrations were determined to be less than 1 wt % and almost all CO_2 was present as $CO_3{}^{2-}$. IR bands for $CO_3{}^{2-}$ were found at 1519 and 1417 cm^{-1}, similar to the positions of the $CO_3{}^{2-}$ bands of MORB compositions (Fine and Stolper, 1985). Despite the fact that these liquids have ~6 wt % total alkalies and Ne# ~ 0.7 [Ne# = Ne*(Ne+$CaAl_2O_4$)], the position of the $CO_3{}^{2-}$ antisymmetric stretch bands is nearly coincident with those of low-alkali compositions, suggesting that the CO_2 speciation model for MORBs is also applicable to natural silica-undersaturated melt compositions. (Authors' abstract)

PANDYA, N., AGGREY, K., MUENOW, D.W. and **SHARMA, S.K.**, 1989, Abundance, speciation and thermal release behavior of H_2O from volcanic glasses (abst.): Eos, v. 70, p. 488. First author at Dept. Chem., 2545 The Mall, Univ. Hawaii, Honolulu, HI 96822.

The abundances, speciation and thermal release behavior of H_2O and other volatiles from a wide range of submarine volcanic glasses have been investigated using a combination of high-T mass spectrometry, infrared and Raman spectroscopy. Glasses studied range from low Mg# tholeiitic basalts to highly evolved andesites with total H_2O abundances from less than 0.20 to >1.5 wt %. From water-release profiles (mass pyrograms) and infrared spectra we are able to determine abundances of molecular and hydroxyl water. A "depth-profile" study for volatiles trapped within a pillow basalt was also made. Results show S, Cl and CO_2 abundances are invariant with sample layer depth beneath the outer glassy rind. At depths greater than 8 mm below the glassy rind a low-T release (<650°C) of molecular H_2O appear and is believed to be due to a combination of influx of seawater (supported by H/D-ratios and Cl-release profiles) and degassing from deeper interior layers. An additional high-T (>700°C) water release begins to appear at deeper sample layers and is believed to be due to the rupture of Si-OH groups in silica-rich regions caused by incipient phase separation. (Authors' abstract)

PANIN, V.Ye., GRINYAEV, Yu.V., ELSUKOVA, T.F., ZHUKOVA, K.P. and **NOVOSELOVA, Ye.M.,** 1989, Inhomogeneity of the distribution of tension and motion of grains as a whole in a deformed crystal: Doklady Akad. Nauk SSSR, v. 309, no. 2, p. 356-359 (in Russian). Authors at Inst. Physical Resistance and Material Science, Tomsk, U.S.S.R.

Pertinent to the inclusion behavior during metamorphic processes. (A.K.)

PARNELL, J., 1989, Genesis of metal-rich bitumens (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-574.

PASAL'SKA, L.F., PROSHKO, V.Ya., KALINICHENKO, A.M., MATYASH, I.V. and **VALASIS, A.G.,** 1989, Sodium in the gas-liquid inclusions in minerals from NMR data: Dopovidi Akad. Nauk, Ukrains'koyi RSR, Seriya B, Geologichni Khimichni Biologichni Nauki, 1989, (12), p. 10-13 (in Ukrainian).

PASCAL, M.L. and **ANDERSON, G.M.,** 1989, Speciation of Al, Si, and K in supercritical solutions: Experimental study and interpretation: Geochim. Cosmochim. Acta, v. 53, p. 1843-1855. First author at C.R.S.C.M., 1A, rue de la Férollerie, F-45071 Orléans, Cedex 02, France.

Corundum and quartz solubilities in KOH-H_2O and NaOH-H_2O solutions were measured at 500-700°C and 2 kbar. For common assemblages such as quartz-mica-feldspar, the (K,Na)Al complex molality is negligible 10^{-6} to 10^{-4}), whereas the experimental Al-concentrations (10^{-3} m) suggest the presence of another Al-bearing species involving both silica and alkalies. (From authors' abstract by E.R.)

PASTERIS, J.D., 1989a, Methane-nitrogen fluid inclusions in igneous rocks from the Duluth Complex, Minnesota (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 51. Author at Dept. Earth and Planet. Sci. and McDonnell Center for Space Sci., Washington Univ., Campus Box 1169, St. Louis, MO 63130.

Most drill cores from the western edge of the Duluth Complex are dominated by troctolites and gabbros, some of which show hydrous alteration of the mafic phases. Drill core FHL-2 (Minn. Dept. of Natural Resources; David Sassani, unpub. analyses) from the Fish Lake area along the southwest margin of the Complex, however, consistently shows very strong petrologic and chemical evidence of melt-country rock reaction, including extensive hydration of pyroxene and olivine, as well as precipitation of abundant K-feldspar and interstitial quartz grains (≤1.8 mm). One thin-section has an intimate association of quartz, spherical masses of lamellar graphite (≤0.8 mm), and patches of chlorite and amphibole. The quartz has abundant 2- to 20-µm FI, which are dominantly one-phase volatile and rarer two-phase aqueous inclusions. Most inclusions lie along fractures and appear S, but some occur as isolated clusters. The relative timing of the volatile and aqueous inclusions is not clear. No solid phases were observed in any of the inclusions, and no FI were observed in the adjacent plagioclase grains.

Preliminary analyses were done on one thin-section (22 inclusions in 4 quartz grains) using a laser Raman microprobe (LRM). All of the one-phase inclusions consist solely of CH_4 and N_2; several inclusions also were analyzed for H_2, CO_2, CO, H_2S, and one inclusion for HCN, C_2N_2, and NH_3. There is a range in composition, but most of the inclusions consist of subequal molar proportions of N_2 and CH_4. LRM analysis of the liquid phase in one 2-phase inclusion confirms it to be water, and analysis of the vapor bubble reveals a weak N_2 but no CH_4 band. The P-sensitivity of the spectral band position for CH_4 (Fabre and Couty, 1986) makes it possible to estimate CH_4 gas P in the volatile inclusions, 11 of which indicate "CH_4 pressures" of 110 bars and 5 of which show 160 ± 25 bars. [Calibration of CH_4 peak position in CH_4-N_2 gas *mixtures* is underway, in collaboration with I.-M. Chou and J.C. Seitz.] There appears to be some correlation between physical properties, composition, and gas P of inclusions in that the somewhat larger inclusions in isolated clusters all lie within the dominant compositional and P ranges given above. The abundance of interstitial quartz and the C-H-N-O composition of the occluded fluids are attributed to local interaction of the mafic Duluth melt with the adjacent Middle Precambrian Virginia Formation, which is in part a carbonaceous, pyritic shale. The FI are *primary* evidence of contamination of the Duluth melt by *volatiles* driven off of the Virginia Fm., a process that has been invoked to explain the sulfur isotope signatures of several ore deposits along the contact (e.g., Ripley and co-workers). It is significant that the volatiles apparently were incorporated into the melt and did not segregate into a separate phase until the end stage of crystallization, during quartz precipitation. It is possible that before their trapping the volatiles already had exsolved into an aqueous and a C-H-N fluid, which would account for the separate populations of inclusions in quartz. The rarity of aqueous inclusions may be due to the consumption of water from the fluid(s) during widespread hydrous alteration of the troctolites. At least locally, both the concentration and speciation (with its fO_2 implications) of these volatiles could have affected the crystallization T and crystallization interval of the melt, which in turn control the timing, composition, and localization of ore deposits (Cu-Fe-Ni sulfides, Fe-Ti oxides, Pt-group elements). (Author's abstract)

PASTERIS, J.D., 1989b, *In situ* analysis in geological thin-sections by laser Raman microprobe spectroscopy: A cautionary note: Applied Spectroscopy, v. 43, no. 3, p. 567-570. Author at Dept. Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington Univ., Box 1169, St. Louis, MO 63130.

Precautions are required in order to eliminate or account for (1) apparent disorder in graphite grains, which is caused by polishing and orientation effects that lead to an enhanced 1350-cm^{-1} graphite band, and (2) the overlap of Raman-active vibrational modes in the mounting medium with Raman bands of the geologic phase of interest. It therefore is always necessary to obtain a Raman spectrum of the specific "matrix" (e.g., quartz mounted with epoxy onto glass) to the phase under analysis—even if the Raman spectrum of the unmounted mineral host is well known—in order to identify interfering Raman bands due to the mounting medium. The latter is particularly important, due to the practice of some thin-section makers who routinely use more than one kind of epoxy in impregnating and mounting the rock section onto the glass slide. (From author's Conclusions)

PASTERIS, J.D., CHOU, I.-M. and SEITZ, J.C., 1989, Raman microprobe analysis of high-pressure fluid standards (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-93-94. First author at Dept. Earth and Planet. Sci., Washington Univ., Campus Box 1169, St. Louis, MO 63130.

Accurate compositional and density data from laser Raman microprobe (LRM) spectroscopy on FI require calibration on gas mixtures of a wide range of known compositions and densities, in a form that can be imaged with a microscope. We analyzed standards in a high-P gas (HPG) cell at controlled P (±1 relative %) from 1 to about 300 bars and in sealed fused-quartz (SGQ) tubes in which known amounts of compounds had been thermally decomposed. From the cell, we determined a calibration curve for CH_4 spectral peak position versus P for pure CH_4 and for gas *mixtures* containing CH_4. Our calibration curve for (pure) CH_4 peak position versus P, having a spectral resolution of about 4 cm^{-1}, is almost indistinguishable from that in the literature having a spectral resolution of ~0.35 cm^{-1}. Spectra of an equimolar mixture of CH_4 and N_2 were taken from 10 to 300 bars; the CH_4 peak position in the gas *mixture* represents CH_4 partial P. Furthermore, the HPG cell permits calibration of the CH_4 peak position for different gas mixtures at various total and partial P. The ratios of Raman quantification factors for different pairs of gases as a function of P are being measured.

Preliminary results show that this ratio: (a) for CO_2:N_2, obtained in SFQ tubes, does not change appreciably up to 120 bars; (b) for CH_4:N_2, obtained in the HPG cell, varies significantly between 140 and 310 bars. (Authors' abstract)

PASTERIS, J.D. and WOPENKA, Brigitte, 1989, Raman spectra of carbonaceous material: Sensitive indicators of degree of metamorphism (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A275.

PATERSON, C.J., UZUNLAR, Nuri, GROFF, J. and LONGSTAFFE, F.J., 1989, A view through an epithermal-mesothermal precious metal system in the northern Black Hills, South Dakota: A magmatic origin for the ore-forming fluids, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 564-570. First author at Dept. Geology and Geol. Eng., South Dakota School of Mines and Tech., Rapid City, SD 57701.

In the northern Black Hills, epithermal to mesothermal Au-Ag-(Pb)-(W) deposits of the sediment-hosted type and the intrusion-hosted type are spatially and temporally associated with an east-west zone of Tertiary (40-60 Ma) alkalic igneous intrusions. Considerable structural relief, together with underground exposure in the Homestake mine, provides a 3-km vertical profile through the Tertiary hydrothermal system.

Au-Ag mineralization occurs throughout the system from thick quartz-pyrite ± galena ± chalcopyrite ± sphalerite ± fluorite ± anhydrite ± biotite ± molybdenite ± cosalite veins in Precambrian schist at depth, to quartz-pyrite-fluorite veinlets and disseminated pyrite in igneous stocks, to silicified arsenian pyrite-marcasite replacement mantos adjacent to vertical fractures in lower Paleozoic sedimentary rocks (calcareous and dolomitic sandstones, limestones) nearer the surface. Stratigraphic reconstruction allows estimation of the range of maximum depths of mineralization from 1.3 to 4 km (0.35-1.1 kbars).

Fluid inclusions in quartz and fluorite in these deposits are diverse. Most fluids have low apparent salinity (<10 eq. wt % NaCl), but saline fluids (up to 63 wt %) and CO_2-rich fluids occur deeper in the composite system. Fluid inclusion Tt range from 400° to 750°C deep in the system to 170° to 240°C at higher levels.

The $\delta^{18}O$ and δD values for the fluids are 6.2 to 11.6 and -53 to -75‰, respectively. The isotopic and FI data together suggest that magmatic water was an important component of the ore-forming fluids. This is in contrast with most epithermal systems which are dominated by meteoric water. The implication is that the alkalic igneous intrusions were the source for most of the Au. The presence of lower $\delta^{18}O$ values at shallower levels (~1 km depth), the abrupt decrease in Tt, and the gradation in fluid salinities suggest that meteoric waters in the aquifers of the basal Paleozoic sequence may have mixed with the ore fluids. This fluid mixing was a likely cause of Au deposition. (Authors' abstract)

PEABODY, C.E., 1989, Cinnabar-petroleum deposits: nature and source of mineralizing fluids (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-582-583.

PEARCY, E.C., 1989, The geology and evolution of the hot spring gold deposit at Cherry Hill, California: PhD dissertation, Dept. Earth and Planetary Sciences, Harvard Univ., Cambridge, MA, 248 pp.

At Cherry Hill, California, Au-precipitating hot springs are associated with an economically significant body of Au mineralization. The deposit is about 0.56 Ma old and has a simple mineralogy: Au-quartz-adularia-carbonate-Fe sulfide microveinlets dominate the ore. The paragenetic sequence consists of 12 stages: early adularia (I), an alternating sequence of silica and carbonates (II-XI) and late sulfate deposition (XII). Au deposition occurred during stages V-VI and IX. Early adularia-sericite alteration in the central part of the deposit was followed by the development of anomalies of Au, Ag, Hg, Sb, Tl and As to the northwest and southeast as well as the central zone. Most recently, strong argillic alteration has developed to the northwest of the central zone. Au anomalies correlate broadly with those of Ag, Hg, Sb, Tl and As.

Early in the history of the deposit T were relatively high (ca 185°C), salinities varied widely (8-14 wt % NaCl eq.), and there was boiling. As the system evolved, T and salinities dropped to the values of the present springs (~55°C and 2.8 wt % tds). Oxidation potential was kept relatively low by abundant hydrocarbons, and fO_2 dropped over time largely in response to decreasing T. Sulfur fugacity fluctuated between pyrrhotite-stable and pyrite ± cinnabar-stable. Fluid pH remained near neutral and was probably buffered mostly by mudstone. $\delta^{18}O$ values of veinlet minerals suggest that the fluids were generally close to equilibrium with mudstone. Au solubility was controlled mainly by changes in fS_2 and ΣS concentration rather than by variations in pH, fO_2, temperature or salinity.

Solid bitumen and/or P fluid inclusions with a vapor bubble and variable proportions of oil and water occur in Stages I-II and VII-XI. Stages during which Au was deposited sometimes trapped bitumen and/or oil (IX) and sometimes not (V and VI). Most of the oils have no n-alkanes and only traces of hydrocarbons in the range C_1-C_{14}. Au contents of the bitumen range from 0.3-37 ppm. The Au in the bitumen is probably the result of encapsulation of preexisting Au by hydrocarbons, entrainment of fine Au particles by petroleum or the scavenging of Au from later hydrothermal solutions. (Author's abstract)

PEARCY, E.C. and BURRUSS, R.C., 1989a, Hydrocarbon fluids at the hot spring gold deposit at Cherry Hill, California (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 52. First author at Dept. Geol. Sci., Harvard Univ., Cambridge, MA 02138.

P FI with a vapor bubble and variable proportions of oil and water occur in Stages VIII through XI of twelve paragenetic stages at the Cherry Hill Au deposit. Oil is most abundant in Stage XI calcite. Au occurs in the absence of oil in Stages V to VII, but does occur with P oil inclusions in stage IX silica.

Th of P oil inclusions decrease from Stage VIII (ave. Th = 158°C) to Stage XI (ave. Th = 100°C). As Th drops, the transmitted light color of the oils changes from orange/brown to blue. All oils fluoresce more intensely with blue light (405-490 nm) excitation than with UV (334-365 nm) excitation. Birefringent, organic solids (daughters?) occur in inclusions with liquid-vapor Th <125°C and are more abundant as Th drops to 100°C.

Oils were analyzed by crushing 1-7 mg. samples in the inlet of a capillary column gas chromatograph programmed from -20° to 300°C with a FID detector. The carbon number (Cn) range of all samples is dominated by an "unresolved hump" in a Cn range from about C16 to C26, quite distinct from normal crude oils. Most samples have no n-alkanes and only one sample has traces of hydrocarbons in the Cn range C1-C14. Inclusions in Stage XI calcite show a slight shift of the maximum of the unresolved hump to lower Cn relative to Stage VIII, and several unidentified, resolvable hydrocarbons.

If the oils in the inclusions were generated by thermal cracking of sedimentary organic matter, they are distinctly different from normal crude oils. The narrow Cn range of the unresolved hump is similar to a distillation fraction and may be caused by volatilization and condensation of hydrocarbons in a low P hot spring environment. The shift in fluorescence color and Cn range as Th declines from Stage VIII to XI suggests preservation of lower molecular weight hydrocarbons as the system cooled. The absence of n-alkanes could be caused by microbial biodegradation. However, the T range of this system (100°-160°C) requires either the presence of organisms that metabolize hydrocarbons at T higher than the maximum for normal petroleum biodegradation (80°C) or that the biodegradation occurred in cooler (<80°C) parts of the system with subsequent migration of hydrocarbons to the site of mineralization. (Authors' abstract)

See also Pearcy and Petersen, 1987, Fluid Inclusion Research, v. 20, p. 306-307. (E.R.)

PEARCY, E.C. and **BURRUSS, R.C.**, 1989b, Gold-organic matter association in the hot springs gold deposit at Cherry Hill, California (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-584. First author at Harvard Univ., Cambridge, MA.

Solutions carrying Au and organic matter were contemporaneous in space and time in the paragenesis at Cherry Hill. Solid bitumen and/or P fluid inclusions with vapor bubble and variable proportions of oil and H_2O occur in Stages I and II and VIII through XI of 12 paragenetic stages. Au deposition occurs in the absence of organic matter in Stages V and VI but does occur with bitumen in Stage VII silica and with P oil inclusions in Stage IX silica. Oil is most abundant in stage XI calcite.

Th of P oil inclusions decrease from stage VII (Th = 178-143°C) to Stage XI (Th = 130-81°C). Aqueous inclusions show a similar trend. Following boiling in Stage II, Th drops from Stage VII (Th = 221-154°C) to Stage IX (Th = 177-100°C). Salinities drop slightly from Stage VII, avg. 3.0 wt % NaCl eq., to Stage IX, avg. 2.7 wt % and to Stage XI, avg. 2.5 wt %. As Th drops the transmitted light color of the oils changes from orange/brown to colorless or light yellow, and fluorescence emission changes from yellow/brown to blue. All oils fluoresce more intensely with blue light (405-490 nm) excitation than with UV (334-365 nm) excitation. Birefringent, organic solids (daughters?) occur in inclusions with liquid-vapor Th < 125°C and are more abundant as Th drops to 100°C.

Oils were analyzed by crushing 1-7 mg samples in the inlet of a capillary column gas chromatograph programmed from -20°C to 300°C with a flame ionization detector. All samples are dominated by an "unresolved hump" in the carbon number (Cn) range from about C16 to C26. Most samples have no n-alkanes and only one sample has traces of hydrocarbons in the Cn range C1-C14. Chromatograms of inclusions in Stage XI calcite show several strong peaks for as yet unidentified hydrocarbons and a slight shift in the maximum of the unresolved hump to lower Cn relative to Stage VIII. These oils are distinctly different from normal crude oils. The narrow Cn range of the unresolved hump is similar to a distillation fraction and may be caused by volatilization and condensation of hydrocarbons in a low P hot spring environment. The shift in fluorescence color and Cn range as Th declines from stage VIII to XI suggests preservation of lower molecular weight hydrocarbons as the system cooled. The absence of n-alkanes could be caused by microbial biodegradation. However, the T range of this system requires either the presence of organisms that metabolize hydrocarbons at T higher than the maximum for normal petroleum biodegradation (80°C) or that the biodegradation occurred in cooler (<80°C) parts of the system with subsequent migration of hydrocarbons to the site of mineralization.

Evidence for direct involvement of organic matter in Au transport and deposition is difficult to identify. Most Au was deposited during precipitation of Stage IX silica that contains P oil inclusions and encloses masses of solid bitumen. To test the involvement of organic matter in Au transport and deposition, five samples of solid bitumen from stage IX were hand picked, dissolved in a polar solvent mixture, and both soluble and insoluble fractions were analyzed for Au, As, Ca, Cd, Fe, Mg, Ni, S, Sb, Se, Sr, and V by neutron activation. Au contents of the soluble fraction ranged from 4 to 120 ppb but were always below the solvent blank (280 ppb). The insoluble fractions contain up to 47 ppm Au and consist of insoluble organic matter, needles of valentinite (Sb_2O_3), and iron oxides. Au cannot be detected by energy dispersive x-ray analysis of individual phases in the insoluble fractions. The valentinite and Fe oxides may be the oxidized remains of stibnite and Fe sulfides associated with bitumen in the ore. The high Au content of the insoluble bitumen fraction suggests organic complexing of Au although a mechanical mixture of microcrystalline or colloidal Au with solid bitumen is possible. (Authors' abstract)

PECK, J.A., BROWN, G.E., Jr., TAIT, C.D. and SWANSON, B.F., 1989, Gold in aqueous chloride solution: Speciation and thermodynamic parameters from Raman and NMR spectroscopy (abst.): Eos, v. 70, p. 1382.

PEDONE, V.A., CERCONE, K.R. and BURRUSS, R.C., 1989, Identification of organic and inorganic activators of photoluminescence in calcite by laser microprobe spectroscopy (abst.): AAPG Bull., v. 73, no. 3, p. 398.

PELISSONNIER, Hubert, 1989, Review of metallogenic concepts and models of lead-zinc deposits in carbonate sedimentary environments: Chron. rech. min., no. 495, p. 37-45 (in French, English abstract). Author at École des Mines, 60, bd Saint-Michel, 75272 Paris Cedex 06, France.

A review (E.R.)

PERCIVAL, J.A., 1989, Melt-induced fluid pumping and the source of CO_2 in granulites, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 61-70.

PERCIVAL, T.J., RADTKE, A.S., BAGBY, W.C., GIBSON, P.C. and NOBLE, D.C., 1989, Bau, East Malaysia: Arsenic-rich sedimentary-rock hosted gold deposits spatially and genetically associated with epizonal magmatism (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A394. First author at Nassau Ltd., 255 Glendale Avenue, Sparks, NV 89431.

The Au deposits of the Bau district have produced 1.2 x 10^6 troy oz of Au and significant Sb and Hg. Based on field work in 1982 and follow-up laboratory work, we conclude that there is a clear genetic association between nearby, calc-alkaline intrusions, vein deposits, and replacement disseminated Au deposits that may provide an important key to understanding the genesis of certain sedimentary-rock hosted precious-metal deposits in the western U.S. and elsewhere, where obvious connections to magmatism are lacking.

Hydrothermal alteration and Au mineralization occur in massive limestone and shale in the core of the Bau Anticline, whose crest is cut by several sets of near-vertical faults. A NE-trending set of regional faults and associated joints and fractures were the P structural controls for Miocene microgranodiorite and dacite porphyry stocks, dikes and sills; they were also the P conduits for Au-bearing hydrothermal fluids. Replacement silicification, argillization, sericitization, and quartz ± calcite veining are widely distributed and locally intensely developed. Silica, native As, stibnite, pyrite, realgar, and local arsenopyrite were precipitated from Au-bearing hydrothermal fluids in brecciated shale and limestone within and adjacent to faults and along limestone-shale contacts. The resulting jasperoid and tabular- to podiform-replacement ore bodies account for most of the district's production. Minor production was from quartz-calcite ± calc-silicate and base-metal sulfide veins. Au-bearing calc-silicate veins spatially related to epizonal intrusions are important genetically and formed early from the evolving hydrothermal system.

P liquid + vapor and S halite-bearing fluid inclusions are present in syn- and(or) post-mineralization quartz in replacement ores and calc-silicate veins. Preliminary data gives Th(V) = 210-240°C and Tm(ice) = -1.0 to -2.6°C for liquid + vapor inclusions in replacement ore and Th(V) = 280-315°C and Th(s) = 185-190°C for halite-bearing inclusions in calc-silicate ore. No KCl or K-Fe-Cl dms have been identified; therefore, a large magmatic fluid input is not proven. Mineralized sedimentary rocks are strongly enriched in Au, As, and Sb and less markedly enriched in Hg (0.2->10 ppm), Tl (0.5-4 ppm), Ag, Zn, and Pb. Local arsenical ores contain >20% As. Au/Ag ratios are variable but are higher for replacement ores (median = 1) than for vein ores (median = 0.2). (Authors' abstract)

PEREZ-ALVAREZ, M.S., 1989, An isotopic and cathodoluminescence study of Pb-Zn deposits from the Basque-Cantabrian Basin (Northern Spain) (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 43. Author at Dept. Geology and Petroleum Geology, Univ. Aberdeen.

The Carranza-Lanestosa ore deposits are located in the gently folded western termination of the Basque Arc in the Basque-Cantabrian Basin (Northern Spain). They are hosted by platform carbonates of Cretaceous age (Pascal, 1985) and show many affinities towards Mississippi Valley-type deposits.

Cathodoluminescence has proved of great value in textural studies and in determining the paragenetic sequence. For Anselma Mine sphalerite and galena are coexisting. Dolomite coexists with both to some extent but it seems to generally predate the sulphides. Fluorite in part coexists with the sulphides and in part postdates them. Calcite postdates the sulphides and coexists with later fluorite. In Matienzo Mine the paragenesis is not well established. Fine-grained pyrite disseminated in the matrix is the earliest phase. This is followed by coexisting galena and sphalerite.

S isotopic measurements have been made on sphalerite and galena from different localities in the area. The formation T deduced from S fractionation between sphalerite-galena pairs agree reasonably with those from fluid inclusion studies, yielding values between 150 and 350°C for Anselma Mine and between 160 and 270°C for Matienzo (Herrero et al., 1986). The $\delta^{34}S$ characteristics shown by each deposit are very different, suggesting that in each case the source of the S and the mechanism of H_2S production were also different. The low $\delta^{34}S_{CDT}$ values in Anselma Mine (-6 to -15‰) indicate that sulphate was only partially reduced either because of a low organic content in the stratigraphic sections in the area of because the H_2S was largely derived by leaching of sedimentary sulphides (Ohmoto and Rye, 1979). On the other hand, Matienzo Mine shows higher $\delta^{34}S$ values, in a range close to 0‰, that seem to indicate that the sulphur was derived from a deep source.

Six carbonates (calcite or dolomite) from mineralised veins have been analysed for their C and O isotopes. The data obtained point to a marine origin for the carbonate carbon (with $\delta^{13}C_{PDB}$ values ranging from 2 to 4‰) and therefore the most likely source is the host rock carbonate. The $\delta^{18}O_{CDT}$ values obtained for the carbonates (between 14 and 21‰) are much more enriched in $\delta^{18}O$ than seawater and are consistent with hot formation waters of marine, meteoric or connate origin. (Authors' abstract)

PETERS, S.G. and GOLDING, S.D., 1989, Geologic, fluid inclusion, and stable isotope studies of granitoid-hosted gold-bearing quartz veins, Charters Towers, northeastern Australia, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 260-273. First author at Central Norseman Gold Corp., P.O. Box 56, Norseman, W. Australia 6443, Australia.

The Charters Towers Au field lies within the mid-Paleozoic Lolworth-Ravenswood block where pre-Ordovician metasedimentary and meta-igneous rocks were intruded by the I-type Hogsflesh Creek and Towers Hill Granodiorites in the Late Ordovician, followed by north- and northeast-trending dike swarms in the Silurian. Early Devonian Millchester Creek Tonalite and Alabama Diorite intruded all these rock types and were in turn intruded by Carboniferous mafic dikes. No direct relationship between any of the granitoid phases and the mineralization has been established.

FI studies indicate a fluid salinity of 5.3 to 11 eq. wt % NaCl with local CO_2 and formation T of between 240° and 300°C. O isotope values of quartz (12.3-15.6‰), muscovite (8.3-8.6‰), and calcite (11.0-14.8‰); H isotope values of muscovite (-57 to -42‰) indicate a fluid composition at these T of 3.2 to 8.4‰ for $\delta^{18}O$ and -62 to -42‰ for δD which overlaps the range of metamorphic and magmatic waters. Sulfide $\delta^{34}S$ values (-1.1 to +4.2‰) and carbonate $\delta^{13}C$ (-4.7 to -3.6‰) are consistent with derivation of sulfur and carbon from juvenile fluids or by dissolution and/or thermal decomposition of magmatic sulfides and carbonates during metamorphism.

The mineralization and alteration style, combined with stable isotope and FI data, is interpreted to indicate that the Charters Towers Au field is the product of deep-seated Devonian magmatism and crustal ± mantle outgassing. (From authors' abstract by E.R.)

PETERSON, J.W. and NEWTON, R.C., 1989a, Melting of phlogopite-quartz-sanidine in the presence of H_2O-CO_2 fluid: Implications for granites and charnockites (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A158.

PETERSON, J.W. and **NEWTON, R.C.**, 1989b, CO_2-enhanced melting of biotite-bearing rocks at deep-crustal pressure-temperature conditions: Nature, v. 340, p. 378-380. Authors at Dept. Geophysical Sciences, Univ. Chicago, 5734 S. Ellis Ave., Chicago, IL 60637.

The role of CO_2 in melting of the Earth's crust has been a topic of considerable debate. Experimental studies in quartz-feldspar systems have shown that CO_2 solubility in simple granitic liquids is less than 1 wt % at P <10 kbar and that dilution of H_2O vapour with CO_2 raises the vapour-saturated solidi, indicating that CO_2 inhibits, rather than promotes, crustal melting. On the other hand, from experiments on the system K_2O-MgO-Al_2O_3-SiO_2-H_2O-CO_2, Wendlandt has inferred significant solubility of CO_2 in crustal melts. Wendlandt observed that biotite-quartz-feldspar assemblages melt to orthopyroxene + liquid as low as 740°C in the presence of CO_2-rich fluids, more than 50°C lower than equivalent orthopyroxene-producing reactions in the pure-H_2O systems. This surprising result implies a fundamental melt interaction between MgO and CO_2, because neither component alone has significant solubility in granitic liquids near the H_2O-saturated solidus. In view of the potentially important consequences of these results for deep-crustal processes, additional data are needed. Here we report the results of experimental melting studies on synthetic biotite-quartz and biotite-quartz-sanidine assemblages. In general agreement with Wendlandt's results, we find that these assemblages melt in the presence of CO_2-rich vapour below 760°C at P <10 kbar, conditions believed to be encountered in high-grade crustal metamorphism. This opens up the possibility that melting of the deep crust may occur in the presence of CO_2-rich fluids. (Authors' abstract)

PETERSON, T.D., 1989a, The nature and origin of primary carbonatite magmas (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-51.

PETERSON, T.D., 1989b, A microprobe study of natrocarbonatite (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-81.

PETERSON, T.D. and **CARMICHAEL, I.S.E.**, 1989, A microprobe study of natrocarbonatite (abst.): Eos, v. 70, p. 491. First author at Geol. Survey Canada, 588 Booth St., Ottawa K1A 0E4, Canada.

We have obtained complete microprobe analyses of the phenocryst minerals and groundmass in samples of natrocarbonatite from Oldoinyo L'engai. Opaques in the groundmass are pyrrhotite-alabandite solutions; manganiferous monticellite is the only silicate phase present. The groundmass contains eutectic intergrowths of carbonates, fluorite, barite, and halite, and is rich in F (4.4%) and Cl (6%). Nyerereite phenocrysts are stable under the beam and yield totals near 100%. They are unzoned, of composition $Cc_{50}Nc_{41}Kc_9$ with 2% SrO (Cc = [Ca, Ba, Sr]CO_3; Nc = Na_2CO_3; Kc = K_2CO_3). Gregoryite phenocrysts volatilize under the beam, yielding total of about 96%, and contain 0.5% F, 0.6% Cl, 4.5% SO_3, and 2% P_2O_5. Cores ($Cc_{18}Nc_{77}Kc_5$) are usually weakly zoned; half zone to more Na-rich and half to more Ca-rich compositions. One is strongly zoned to $Cc_{22}Nc_{72}Kc_7$; such zoning is predicted from isothermal sections in the ternary Cc-Nc-Kc. All have sodic overgrowths ($Cc_{15}Nc_{81}Kc_4$) relatively enriched in P_2O_5 and depleted in SO_3. Reverse zoning was probably caused by release of P, enlarging the field of gregoryite + liquid; sodic overgrowths presumably developed in the lava lake at 1 bar. Whole-rock and groundmass compositions plot closely together in Cc-Nc-Kc and on the Cc side of the gregoryite-nyerereite cotectic, suggesting the lavas are themselves cotectic liquids and that additional components (K, F, etc.) have perturbed the location of the cotectic. It is not possible to determine from our samples or from previously published data whether the primary magma had gregoryite or nyerereite on the liquidus. (Authors' abstract)

PETROS'YANTS, P.B., 1988, P-T-X-E parameters of fluid and environment-determining characteristics of a geochemical process: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 25-26 (in Russian). Author at Rostov State Univ., Rostov, U.S.S.R.

For the mineral-forming fluids of Tyrnyauz deposit the following semiquantitative characteristics have been obtained: PCO_2 0.6-6.5, PS 0.2-0.9 atm, $CaCO_3$ 0.01-0.9%, T 900-1400 K (zone of high-T border streams) [sic, A.K.], 500-650 K (W-Mo ores). E means vectors of electric-magnetic fields. (A.K.)

PETROV, P.P., 1989, Fluid inclusions in quartz from vein polymetallic ore deposits in the Rhodope Mts., Bulgaria (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 73. Author at Dept. Geochem., Univ. Sofia, Sofia-1000, Bulgaria.

In the Rhodope mountains, Bulgaria, Tertiary vein deposits, polymetallic ore minerals are associated with quartz. Microscopic investigation of individual FI has revealed two generic types of liquid-gas inclusions. The P inclusions are of two types, referred to here as sectorial and intercrystalline types. The sectorial inclusions occur parallel to the rhombohedral sectors of the quartz crystals. Here the inclusions walls have a characteristic spiral structure. The intercrystalline type inclusions are situated in between the crystals of the compact quartz aggregates. These inclusions have perfectly flat walls and their form depends on the spacial relationship of the quartz crystals. S and PS fracture type inclusions have different phase ratios which depend on the period of fixing and the relative heating rate. It has been established that the inclusion habit depends on the relative rate of fracture healing, their morphology and in some cases on the presence of autonomous parts of the crystals. (Author's abstract)

PEUCKER, B., 1989, Geochemistry of the Bavarian prismatic quartzes (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 145 (in German) (supplementary issue to European J. Mineral., v. 1.).

The samples of Lower Triassic quartz were collected along the 70 km-long profile of the N and central Bavarian Pfahl. Fluid inclusions in the quartz typically contain solutions rich in K and Ca, that probably were caused by incongruent hydrolysis of feldspars, resulting also in kaolinite and sericite. The younger drusy quartz yielded Th ca. 250°C. Isotopic data on D and O in fluid inclusions indicate values typical of the formation and geothermal waters. (From the author's abstract translated by A.K.)

PHILIPPOT, Pascal and **SELVERSTONE, Jane**, 1989a, Fluid inclusions in eclogite veins: Evidence for fluid heterogeneities and high-field-strength element mobility (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359. Authors at Dept. Earth and Planetary Sciences, Harvard Univ., Cambridge, MA 02138. [Note: Verbal presentation cancelled. (E.R.)]

P and PS fluid inclusions (FI) occur in oscillatory and sector-zoned omphacite (omp) in eclogite veins from the Italian Western Alps (Philippot, 1987, Geodin. Acta, 3, 171-181). The FI occur in planes parallel to (001) faces and in clusters localized in omp cores and sectors. Estimated P-T conditions of the eclogite facies metamorphism are $P \geq 11$ kb and $450 \leq T \leq 550$°C.

The FI contain liquid, vapor and up to five dms at room T. Final melting (Tm) and Th are $-3 \leq Tm \leq -12.5$°C and $120 \leq Th \leq 220$°C with two maxima at -7°C and 150°C, respectively. Therefore, the fluids (excluding dm) are low to moderate salinity (4.5-16.5 wt % NaCl eq.) and high density aqueous solutions. There is no evidence for other components such as N_2 or CO_2. Microprobe analyses of dm in open FI indicate calcite, dolomite, KCl, NaCl?, anhydrite/gypsum, barite, baddeleyite, rutile, pyrite, Fe oxide and albite. Within one sample, Tm, Th and dm contents in FI are consistent within one cluster but vary significantly between clusters and from one grain to another.

Detailed microprobe traverses carried out normal to the (001) face in four oscillatory zoned omp from a single vein show that there is no correlation of chemical zoning patterns or of location of FI bands between grains. In all cases, however, FI are confined to diopside-rich growth zones, implying a connection between omp growth and fluid composition. Within these zones, FI are surrounded by 5-10 µm jadeite-rich haloes, suggesting post-entrapment reaction with the host, e.g., $omp + CO_2 \rightarrow jd + dol + qtz$, which may explain the absence of CO_2 in FI.

The presence of ecologite veins indicates $P(fluid) \geq P(load)$ at >40 km, but variations in FI composition and the lack of correlation of omp zoning between grains imply that the scale of fluid equilibration was small. We suggest that fluid heterogeneities existed on a mm scale in open veins during subduction in contrast to many low-P rocks. The dm suite further indicates transport of high-field-strength elements (Ti, Zr) in subduction zone fluids. (Authors' abstract)

PHILIPPOT, P. and SELVERSTONE, J., 1989b, Fluid heterogeneities, migration pulses and channelized flow of eclogite facies fluids: Evidence for Zr, Ti, Ba, K mobility in subduction zones (abst.): Eos, v. 70, p. 1377. Authors at Dept. Earth and Planetary Sciences, Harvard Univ., Cambridge, MA 02138.

Devolatization of the subducted slab and hydration of the mantle is required to model island arc-magma genesis, crust/mantle geochemical recycling and thermal structure of subduction zones. However, little is known about the composition of HP-LT fluids and the mechanisms by which fluids escape into the mantle. Ecologitic rocks from paleosubduction zones are the best available samples to constrain these two problems.

Extensional fractures, shear fractures and tension-gashes form a complex fracture network in eclogitic rocks from the Monviso ophiolitic complex of the Italian Western Alps. All veins contain omphacite (omp) ± garnet ± rutile ± apatite, suggesting that veining occurred during ecologitic metamorphism at $P \geq 11$ kb and $450 \leq T \leq 550$°C. P fluid inclusions (FI) occur in oscillatory- and sector-zoned omp crystals. The FI contain liquid, vapor and up to five daughter minerals (DM). Microthermometric analyses (MA) show that the fluids (excluding DM) are low to moderate salinity and high density aqueous solutions. DM are calcite, dolomite, albite, $CaSO_4$, $BaSO_4$, ZrO_2, TiO_2, KCl, Fe oxide. Within one sample, MA and DM contents in FI are consistent within one cluster but vary significantly between clusters and from one grain to another. Microprobe traverses carried out normal to the (001) face in four oscillatory-zoned omp from a single vein show that there is no correlation of chemical zoning patterns or of location of FI bands between grains. In all cases, however, FI are confined to diopside-rich growth zones, implying a connection between omp growth and fluid composition.

The eclogite veins indicate conditions of $P(\text{fluid}) \geq P(\text{load})$ at >40 km, from which we assume channelized fluid motion throughout a connected fracture network under a high-fluid P gradient. Crack-seal vein formation and oscillatory zonation suggest that veining proceeded discontinuously, i.e., devolatization/migration/crystallization pulses. Variations in FI composition and the lack of correlation of omp zoning between grains imply that the scale of fluid equilibration was small (i.e., mm scale heterogeneities). The DM suite further indicates transport of high-field-strength (Zr,Ti) and lithophile elements (Ba, K), whose relative abundances in island arc volcanic rocks are widely used to model magma genesis and possible source materials for calc-alkaline rocks. (Authors' abstract)

PHILLIPS, D., ONSTOTT, T.C. and HARRIS, J.W., 1989, $^{40}Ar/^{39}Ar$ laser-probe dating of diamond inclusions from the Premier kimberlite: Nature, v. 340, p. 460-462. First author at Dept. Geology and Geophysical Sciences, Princeton Univ., Princeton, NJ 08544.

Inclusions encapsulated by diamonds at the time of their formation provide a means for determining diamond crystallization ages and the chemistry of the surrounding upper mantle at that time. Sm-Nd studies of peridotitic inclusions, from Cretaceous-age kimberlites in southern Africa, suggest that the diamonds formed 3.3 Gyr ago. Pre-entrapment equilibration of the inclusions with an ^{36}Ar-rich fluid is the most probable explanation for the low non-radiogenic ($^{40}Ar/^{36}Ar$) composition. (From authors' abstract by E.R.)

PINEAU, F. and JAVOY, M., 1989, Carbon isotope geochemistry at convergent margins and fluid exchanges at mantle-crust boundaries (abst.): Eos, v. 70, p. 1380. Authors at Laboratoire de géochimie des isotopes stables, IPGP et Université de Paris VII, 4 place jussieu, 75251 Paris cedex 05, France.

The $\delta^{13}C$ of volcanic CO_2 in subduction zones varies in the range -1 to -13‰ PDB. Although the majority of $\delta^{13}C$ values in oceanic (Mid Ocean Ridges and Oceanic Islands) volcanic gases lie in a more restricted range, the total range in $\delta^{13}C$ of Oceanic samples is very similar to that of subduction zones. We find also the very same range in CO_2 FI from granulite facies. In the latter case the $\delta^{13}C$'s seem to be positively correlated with CO_2 densities, that is with pressure. Similarly the $\delta^{13}C$'s of CO_2 from subduction zones aerial volcanoes is correlated with the thickness of the crust, that is, the P at the basis of this crust. In the granulite facies of the Bamble area CO_2 FI of $\delta^{13}C$'s between -4 and -8‰ are associated with injected mafic magmas which contain carbon concentrations of 300 to 1600 ppm of corresponding $\delta^{13}C$'s between -21 and -12‰. These results indicate that these $\delta^{13}C$ variations are not related to source effects because they should be different in different contexts, and the pressure correlation strongly suggest that they are linked to solubility effects.

All these features point to the fact that $\delta^{13}C$ variations in subduction zones are linked to variable outgassing phenomena and that possible CO_2 transfers from mantle to crust occur mainly via outgassing of mafic magmas at any level of the crust. (Authors' abstract)

PIRONON, J. and **BARRES, O.**, 1989a, Quantitative FT-IR microanalyses using synthetic hydrocarbon fluid inclusions (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 74. First author at Centre de Récherche sur la Géol. de l'Uranium, GS CNRS-CREGU, BP 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Recently, we have adapted an optical microscope for use with an infrared beam to allow the microanalysis of FI by Fourier Transform infrared spectrometry. In order to calibrate this technique, we used a Bruker IFS 88 spectrometer/A-590 microscope together with synthetic FI in KCl containing different hydrocarbons at various concentrations. Inclusions in the range 20 to 30 μm were chosen to obtain undersaturated spectra. KCl was selected to prevent absorption between 4500 and 1000 cm^{-1}.

Peak-area ratios were measured of different bands assigned to C-H vibrations in stretching and bending ranges and compared with results obtained from liquid samples. In the case of neat n-alkanes, cyclohexane and natural oil, we observed an intense perturbation of the absorbance and a widening of the peaks. Micro-Raman analyses proved that there is no difference and no modification between the initial liquid and the liquid trapped in the inclusions.

Some inclusions were synthesized with different concentrations of CCl_4. When the concentration of solvent increases, the $\nu CH_2/\nu CH_3$ ratio approximates to the liquid ratio for n-alkanes and natural oil, and the spectral distortion of cyclohexane inclusions lessens. No modification occurs for liquid film between two NaCl slides and for benzene inclusions. To find the origin of this spectral distortion, we tested the effect of internal P, molecular interaction, inclusion shape, refractive index and other optical parameters. In conclusion, we believe this phenomenon makes quantitative microanalysis of hydrocarbon FI impossible unless the concentration of methyl and methylene groups is low. (Authors' abstract)

PIRONON, J. and **BARRES, O.**, 1989b, Microspectrometric analyses of synthetic and natural hydrocarbon fluid inclusions (UV fluorescence, Raman, FT-Infrared) (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 53. First author at Centre de Recherches sur la Géol. de l'Uranium and GS CNRS-CREGU, BP 23, 54501 Vandoeuvre-lès-Nancy Cédex, France.

Hydrocarbon FI represent one of the most important witnesses of the petroleum migration history in sedimentary basins. Consequently the knowledge of their composition is the main point to understand the (bio)chemical and thermal evolution of the oil. Today some global analyses (GC-MS) are developed but their use is critical: it is difficult to avoid the contamination by the organic matrix and it is impossible to distinguish the different generations of inclusions. Then, analysis of individual FI is the only way for getting reliable geochemical information.

Three non-destructive microprobe techniques were applied to the in situ analysis of the hydrocarbon FI: micro UV fluorescence, Fast Fourier Transform Infrared microspectrometry and multichannel Raman microspectrometry. These techniques were tested on natural oil inclusions and synthetic oil or n-alcane inclusions. The size of the studied inclusions range from 20 μm to 100 μm. The inclusions are located in different transparent crystals such as feldspar, quartz, halite, sylvite and fluorite.

The main information obtained by UV fluorescence concern the localization of the fluorescent inclusions and permit the comparison of emission spectra which are not clearly yet attributed to molecular functional groups.

MicroRaman analyses concern the hydrocarbon inclusions with a low level of fluorescence and permit the qualitative detection of CH_4, CO_2, N_2, graphite and the C=O, CH_2, CH_3, C=C and ring groups.

Nowadays FT-IR microspectrometry seems to be the more efficient spectroscopic technique even if the size of the inclusions is limited to 20 μm and if the absorption of the host mineral is important. This technique permits the qualitative detection of CO_2, H_2O and CH_4 and the C=O, CH_2, CH_3, C=C and ring groups. A semi-quantitative approach was realized in the stretching and bending ranges by comparison of the functional methyl and methylene groups. The CH_2/CH_3 ratio is a good parameter to distinguish the natural hydrocarbons, but the absorbance of the inclusions spectra presents an important distortion. In order to explain this distortion, some inclusions were synthesized with different concentrations of n-alcane in CCl_{14} [CCl_4?]. When the concentration decreases, the CH_2/CH_3 ratio increases up to approximate to the ratio observed for a free n-alcane liquid. So, the infrared microspectrometry seems to be a good qualitative technique for the study of hydrocarbon FI, and can be used in semi-quantitative mode for inclusions of low n-alcanes concentration. (Authors' abstract)

PITMAN, J.K. and **BURRUSS, R.C.**, 1989, Diagenesis of hydrocarbon-bearing rocks in the Middle Ordovician Simpson Group, southeastern Anadarko basin, Oklahoma, *in* K.S. Johnson (ed.), Anadarko Basin Symp. 1988: Oklahoma Geol. Surv. Circular 90, p. 134-142. First author at U.S. Geological Survey, Reston, VA 22092.

Quartzarenites and subarkoses in the Middle Ordovician Simpson Group in the Gulf Costello No. 1 and Sunray-DX parker No. 1 Maxur wells, southeastern Anadarko basin, have undergone a complex diagenetic and petroleum-migration history. During early burial, petroleum migrated locally through sandstones; patches of bitumen in calcite and bitumen-lined quartz overgrowths containing oil-bearing inclusions reflect the introduction of petroleum-bearing fluids at shallow depths. Stable-isotope data reveal that early calcite precipitated at near-surface T from fluids dominated by marine carbon. At moderate to deep burial, calcite dissolution, followed by ferroan-dolomite and clay-mineral precipitation, occurred at about the same time as the rocks reached levels of thermal maturity sufficient for the generation of hydrocarbons. Maximum paleotemperatures during deep burial are estimated from maturation models to have reached 250°F in the Costello well and 300°F in the Mazur well. Maturation-derived T in the Costello well are consistent with preliminary Th (210-250°F) for oil inclusions along microscopic healed fractures that formed during deep burial, thus supporting an Early to Middle Pennsylvanian timing for the generation and migration of late-stage hydrocarbons. The early petroleum phase, emplaced while the rocks were at shallow burial depths, migrated from mature source rocks deeper in the basin. (Authors' abstract)

PITZER, K.S., 1989, Fluids, both ionic and nonionic, over wide ranges of temperature and composition: Pure & Appl. Chem., v. 61, no. 6, p. 979-988. Author at Dept. Chemistry and Lawrence Berkeley Laboratory, Univ. California, Berkeley, CA 94720.

After a brief historical review of the determination of standard state properties of hydrocarbons, the present status of nonideal gas and liquid state properties is considered. The accuracy to which various fluids follow the acentric factor system is examined. The shapes of vapor-liquid and liquid-liquid coexistence curves are considered with comparisons of theory and experiment for both short-range and long-range attractive forces. The effective critical exponent β_e is a sensitive measure of the shapes of these curves. Systems with short-range forces have low β_e throughout the entire range of T and never approach the high values of mean-field theories. Ionic systems show $\beta_e \cong 0.5$ over wide ranges of T. The apparent conflict between the theoretical value 0.325 and a reasonable extrapolation of the experimental β_e to 0.35-0.36 for Ar and Xe at the critical T is discussed in relation to the model used in current theory and the desirability is expressed for a better model for the vapor-liquid system. An equation of state is described for $NaCl-H_2O$ which is valid at the critical point of H_2O and over the coexistence surface to 873 K. Equations are considered for mixed aqueous electrolytes of unlimited complexity valid for liquid-like densities. Recent results for Na_2SO_4 (aq) to 573 K are described, together with their use in predictions of solubilities in both $Na_2SO_4-H_2O$ and in $Na_2SO_4-NaCl-NaOH-H_2O$. (Author's abstract)

PLOEGSMA, Maarten, 1989, Shear zones in the West Uusimaa area, SW Finland: PhD dissertation, Free Univ. Amsterdam (in Dutch, English abstract).

The South Svecofennian volcanic belt (SSB) in SW Finland consists of strongly deformed volcano-sedimentary rocks intruded by early- to late-Svecofennian plutons and is bounded by large late-Svecofennian K-rich granites related to migmatization. The SSB shows domains which strongly vary in style and intensity of deformation, and the West Uusimaa area is the central, diamond-shaped part of this belt. The southern part of the West Uusimaa area has been metamorphosed at amphibolite facies conditions, while the northern part is formed by the West Uusimaa Granulite Complex, both areas representing high T, low P metamorphism. This study was aimed at gaining a better understanding of the structural framework of the West Uusimaa area, with emphasis to the role of shear zones in the thermotectonic history. This was done by a regional correlation of deformation structures, a pilot Rb-Sr dating of a late shear zone, and a study of fluid inclusions in shear zones, focussed on the Suomusjärvi shear zone in the West Uusimaa area and the Hovdefjell-Vegårshei augengneiss in SE Norway.

Whole-rock data from the ultramylonitic banding indicate that heterogeneous rehomogenization of the Rb-Sr isotope system took place at the millimeter scale, giving a meaningless whole-rock age of 1765 ± 105 Ma. From chemical analyses and the isotope data, it is concluded that the compositional differences between the bands were strongly controlled by a heterogeneous flow of locally derived K-rich fluids during the deformation, resulting in differentiation, replacement of plagioclase by K-feldspar, and loss of Ca, Sr and Na.

The combined results of microstructural and fluid inclusion data of the Suomusjärvi tonalite and ultramylonite indicate that in this tonalite, an early CO_2 fluid inclusion population compatible with the regional amphibolite-facies conditions is overprinted by low-grade (±350°C, 1 kb) H_2O fluids which are directly related to D_3 shear zones, often in planes parallel to them. The fluid inclusion data from the Hovdefjell-Vegårshei augengneiss suggest an early H_2O-poor CO_2-N_2-rich fluid population. It is not possible to determine whether the present CO_2-N_2 distribution reflects the one during intrusion or a redistribution caused by the (contemporary) high-grade mylonitization. H_2O- and re-equilibrated CO_2 intrusions are clearly related to late-stage mylonitization and alteration, but the P-T conditions can not be inferred. The nature of the pure-H_2O inclusions suggests that this fluid can not have been the cause of the widespread resetting of Rb-Sr isotopic ages in SE Norway. (From author's abstract by E.R.)

Fluid inclusions in the shear zones are discussed on p. 75-111. (E.R.)

PLUMLEE, G.S., 1989, Processes controlling epithermal mineral distribution in the Creede mining district, Colorado: PhD dissertation, Dept. Earth and Planetary Sciences, Harvard Univ., Cambridge, MA, 378 pp.

This study examines geologic, chemical, and hydrologic controls on mineral distribution in the Creede, Colorado, epithermal system. This work expands upon extensive research at Creede by many investigators, and develops interpretations which are the best possible of voluminous data from complex ore deposits.

Ore petrology studies show that mineral distribution within the Bulldog Mountain (BDM) vein system was influenced by closing (opening) of fractures by mineral deposition (leaching) and structural activity during mineralization. Six BDM paragenetic stages are identified and correlated with stages in other central and southern district vein systems; spatially zoned stages reflect the chemical evolution of hydrothermal fluids in response to boiling and mixing.

Chemical modeling suggests that hydrothermal brines initially boiled to varying degrees in the OH, P, northern exposed BDM, and central Amethyst vein systems: limited boiling deposited chlorite, pyrite, hematite, quartz, and fluorite with lesser base metal sulfides; more extensive boiling produced quartz, fluorite, adularia, and hematite. After boiling, the hydrothermal fluids mixed to the south with dilute overlying groundwaters. Initial mixing deposited sphalerite- and galena-rich assemblages; continued mixing produced progressively greater amounts of barite, native Ag, and acanthite along the southern Amethyst and BDM vein systems.

Botryoidal pyrite, marcasite, and other late-stage sulfides record the collapse of the waning Creede hydrothermal system (Part III). Mineral distribution and textures indicate periodic shifts to vapor-dominated conditions. Steam and other gases boiled from deep hydrothermal fluids and formed a vapor-dominated zone: pyrite and marcasite were deposited when H_2S condensed into Fe-bearing groundwaters descending along fracture walls into this zone. Periodic mixing between hydrothermal fluids and groundwaters may have also occurred. Low groundwater T (<120°C) promoted enrichments of As, Sb, and Ag (up to 16 wt % in the pyrite). Extreme sulfur isotope variations (-44 to +48‰) reflect increased proportions of isotopically variable sedimentary sulfur and the effects of kinetic isotope fractionations. Similar botryoidal pyrite and marcasite occur in the low-T late stages or fringes of many hydrothermal deposit types, suggesting some common mechanisms of formation. (Author's abstract)

POGUE, R.F. and **ATKINSON, Gordon,** 1989, Solution thermodynamics of first-row transition elements. 2. Apparent molal volumes of aqueous $MnCl_2$, $Mn(ClO_4)_2$, $CoCl_2$, $Co(ClO_4)_2$, $FeCl_2$, and $Fe(ClO_4)_2$, from 15 to 55°C: J. Chem. Eng. Data, v. 34, p. 227-232.

POKROVSKII, V.A. and **HELGESON, H.C.,** 1989, New estimates of thermodynamic properties of aqueous aluminum species in the system Al_2O_3-H_2O-NaCl to 5 kb and 1000°C, using the modified Helgeson-Kirkham-Flowers equation of state (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A156.

POLYA, D.A., 1989, Chemistry of the main-stage ore-forming fluids of the Panasqueira W-Cu(Ag)-Sn deposit, Portugal: Implications for models of ore genesis: Econ. Geol., v. 84, p. 1134-1152. Author at Dept. Geology, The University, Manchester M13 9PL, England.

Panasqueira is a large quartz-dominated, W-Cu(Ag)-Sn-rich vein deposit in northeastern Portugal. It is associated with a postkinematic greisened S-type granite and is largely hosted by pelitic schists, previously regionally metamorphosed to greenschist facies grade ($P_{fluid} < 2$ kbar, $T < 400°C$).

The main-stage Panasqueira ore-forming fluids had T of 230° to 360°C, P of generally <500 bars, and 1 to 2 *m* NaCl (Kelly and Rye, 1979). A typical composition of the ore-forming fluid at 300°C and 1 *m* NaCl is estimated to have been 0.2 *m* ΣK, 0.0005 *m* ΣFe, 0.02 *m* ΣCa, 0.02 *m* ΣMg, pH = 5 to 6, log fO_2 = -34 to -35, log fS_2 = -12.5, log ΣS = -2.5. Such a fluid is essentially in equilibrium with the granitic assemblage, quartz + K feldspar + albite + muscovite at around 400°C. Readily leachable sulfides and wolframite within the subjacent granitic bodies are therefore possible major sources of Sn, As, Cu, Zn, and W in the ore veins.

Calculated solubilities of wolframite and cassiterite in the described typical ore-forming fluid suggest W and Sn concentrations of around 0.2 and 5 ppm, respectively. Combined with estimates of the total mass of hydrothermally introduced W and Sn in and around the deposit, these calculations suggest a total ore-forming fluid flux of at least several hundred km^3. Such large fluid fluxes would be difficult to achieve through the single-pass release of magmatic or metamorphic fluids. A model of ore formation involving a multiple-pass fluid flow system is therefore proposed. (Author's abstract)

PORSHNEV, N.V. and **BONDAREV, V.B.,** 1989, Hydrocarbons of the range C_1-C_{11} in high-temperature geothermal waters. Quantitative variations and modes of formation: Doklady Akad. Nauk SSSR, v. 306, no. 3, p. 708-712 (in Russian).

In connection with the hydrothermal petroleum found in the rift zones and having T 315°C, the paper discusses certain possible modes of thermal generation of the hydrocarbon compounds in hydrothermal systems of the deep and subsurface levels. Hydrochemical and mineralogical conditions strongly influence the final composition and structure of the synthesized hydrocarbons (chain, ramified, alkanes, naphthenes, aromatic hydrocarbons, etc.). On the basis of experimental data and natural observations, one may tentatively conclude that in high-T hydrothermal systems the transformations of the organic substance and formation of the C1-C11 hydrocarbons are strictly connected with pyrolysis at 1000 ± 200°C and with reactions at 300 ± 100°C reflecting the conditions of thermolysis and thermocatalysis, respectively. (A.K.)

PORTNOV, A.M., VLASOVA, E.V. and **KHITAROV, D.N.,** 1987, Pressure of CO_2 as a principal cause of ore transport and deposition in shallow gold-silver deposits: Geologiia Rudnykh Mestorozhdenii, v. 29, no. 4, p. 111-114 (in Russian; see Translations).

POULSON, S.R. and **OHMOTO, Hiroshi,** 1989, Devolatilization equilibria in graphite-pyrite-pyrrhotite bearing pelites with application to magma-pelite interaction: Contrib. Mineral. Petrol., v. 101, p. 418-425. Authors at Dept. Geosciences, The Pennsylvania State Univ., University Park, PA 16802.

The proportions of species in a C-O-H-S fluid in equilibrium with graphite, pyrite and pyrrhotite were calculated for a range of P, T and fO_2 conditions, using the equilibrium constants and mass balance method, for ideal and non-ideal mixing in the fluid. Under typical metamorphic conditions, H_2O, CO_2, CH_4 and H_2S are the principal fluid species with H_2S favored by higher T, lower P and lower fO_2 conditions. The dominance of H_2S in the fluid at high T leads to values of XH_2O becoming significantly <1, and causes hydrous minerals to dehydrate at lower T than the case when $XH_2O = 1$. The production of H_2S-bearing fluids provides a mechanism for the selective transfer of S from a graphite-pyrite-pyrrhotite bearing pelite into a pluton via a fluid phase, without requiring wholesale melting and assimilation of rocks. Such a process is feasible if a magma is intruded by stoping, which allows a significant volume of pelite country rock to be raised rapidly to T approaching that of the magma. H_2S-bearing fluids produced from graphite-pyrite-pyrrhotite pelites (due either to magmatic intrusion or regional metamorphism) may also mobilize ore-forming metals as sulfide complexes. (Authors' abstract)

POUTIANEN, Matti, 1984, Composition and conditions of formation of fluid inclusions in topaz from Altenbergin granite greisen stock, DDR: MS thesis, Univ. Helsinki, 63 p. (in Finnish).

POUTIAINEN, M., 1989, Evolution of a metamorphic fluid during progressive metamorphism in the Joroienen-Sulkava area, southeastern Finland, as indicated by fluid inclusions (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 75. Author at Dept. Geol., Univ. Helsinki, Finland.

FI in the progressively metamorphosed Joroinen-Sulkava area, located in the southeastern end of the Raahe-Ladoga zone near the Archaean-Proterozoic boundary, fall into four main categories: (1) H_2O-rich, (2) CO_2-rich, (3) mixed H_2O-CO_2 and (4) CH_4-N_2 inclusions. The samples were collected from quartz veins associated with different deformation phases (D_2-D_4), from metapelites and D_3-D_4 granitoids. The progressive stage of metamorphism culminated 1830-1810 Ma ago mainly during the D_2 deformation. The age of metamorphism and D_2 deformation youngs with the increase in metamorphic grade from amphibolite to granulite facies.

Regionally distribution of the different fluid types indicates a change in fluid regime from an H_2O to CO_2 dominated fluid during the progressive stage of the metamorphism. The change in fluid composition is controlled by partial melting and anatexis of the metapelites. Density data of early CO_2 inclusions in combination with estimates of metamorphic T in the different metamorphic zones indicate a P range of 3.5-5.0 kb which is consistent with data derived from mineral geobarometry. CH_4-N_2 inclusions occur in D_2 and D_3-D_4 quartz veins mainly outside the area affected by anatexis. They are absent from D_3-D_4 granitic veins. Breakdown reactions of biotite may be responsible for the N_2 content of the CH_4-N_2 inclusions. The intrusion of microcline granite (D_4) from somewhat lower crustal level to the metamorphosed metapelites in the granulite facies domain is indicated by early CO_2 inclusions. Evolution of the fluid phase culminated during the D_3-D_4 deformation stages and the density of the associated FI types indicate an influx of these fluids at P below 3 kb. (Author's abstract)

POWELL, M.D. and **KYSER, T.K.**, 1989, Development of laser ablation techniques for stable isotope analyses (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-130. Authors at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

Recent advances have been made in laser ablation techniques for stable isotopes. A system has been developed wherein small mineral samples are ablated under vacuum by a focused beam from a Nd:YAG laser and the products analyzed directly with a MAT 251 mass spectrometer. Results from samples analyzed previously using conventional techniques indicate that energy density is the crucial factor for good results from the ablation process. The energy density is determined by the spot size, which is controlled by focusing, and the beam energy, which is controlled via the laser. The Q-switched output mode of the laser tends to atomize the sample, whereas long pulse output mode primarily heats the sample. The system has been used thus far for three types of analyses. Ablation of calcite from limestones releases CO, CO_2, and some H_2O, whereupon the CO_2 is analyzed for its carbon and oxygen isotopic composition. Results obtained from carbonate analyses indicate that a complex mass fractionation process occurs unless the energy density is maximized. The second type of analysis uses the ability of the laser pulse to disrupt and melt the crystal structure of illite, thereby facilitating the release of interstitial and structural water which is converted to hydrogen gas and analyzed. δD values from laser ablation can be lower by up to 30‰, relative to the values obtained from conventional techniques, because water can remain in the glass if the energy density is too low. The third technique uses the impact of the laser pulse to crack halite crystals, thus releasing the water contained inside FI for analysis. δD values for FI obtained using the laser ablation technique agree well with those from conventional decrepitation or crushing techniques despite the very small sample needed for ablation relative to decrepitation or crushing. The laser system will allow stable isotopic determinations to be made on very small mineral samples "in situ" thus nullifying the need for larger samples obtained from laborious separation techniques. (Authors' abstract)

PRICE, J.G., KYLE, J.R., PRIKRYL, J.D., AGEE, W.N., Jr., BOARDMAN, S.C. and **WOLERY, T.J.,** 1989, Calculating freezing point depressions of multi-component aqueous solutions, with applications to fluid inclusions research (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A358. First author at Nevada Bureau of Mines and Geology, UNR, Reno, NV 89557.

A thermodynamic method is devised to calculate freezing points of multi-component aqueous solutions. Freezing points of solutions of known or assumed compositions can be calculated and compared with measured Tm ice in frozen fluid inclusions.

Freezing point depressions can be calculated by considering the simple reaction: H_2O (c, ice) = H_2O (l, water). Because ice is essentially pure, the law of mass action provides an expression for the activity of water, a_w, as a function of temperature T and pressure P:

$$-RT\,ln(a_w) = \Delta H^{\circ} - T\Delta S^{\circ} + \Delta V^{\circ}(P-1)\,. \qquad (1)$$

Over the narrow range of T and P found in freezing fluid inclusions, ΔV° can be considered constant. On the other hand, ΔH° and ΔS° vary with T, and heat capacity for the reaction enters into the equation: $\Delta Cp^{\circ} = a + bT$. The expression for T as a function of a_w then becomes:

$$f(T) = 0 = \Delta H_{Tr}{}^{\circ} + a(T-Tr) + 0.5b(T^2-Tr^2) + \Delta V^{\circ}(P-1) + T\{R\,ln(a_w) - \Delta HTr^{\circ}/Tr - a\,ln(T/Tr) - b(T-Tr)\}\,. \qquad (2)$$

Standard state properties are: $\Delta HTr^{\circ} = 6008$ J $mole^{-1}$ (Osborne et al., 1939); a = 91.79 J $mole^{-1}$; b = -0.1966 J K^{-2} $mole^{-1}$ (Pitzer and Brewer, 1961); $\Delta V^{\circ} = -0.163$ J bar^{-1} $mole^{-1}$ (CRC, 1984); Tr = 173.15 K.

The geochemical aqueous speciation program EQ3NR (Wolery, 1983) is used to approximate a_w at Tr. T is solved from Equation (2) using Newton-Raphson iterations, starting with T estimated from Equation (1). This method reproduces experimentally determined freezing point depressions for binary systems (H_2O-NaCl, -$CaCl_2$, -$MgCl_2$, -KCl, -HCl, -Na_2SO_4, -Mg_2SO_4, -Na_2CO_3, and -$NaHCO_3$) and for ternary systems (H_2O-NaCl-$CaCl_2$, -NaCl-$MgCl_2$, and -NaCl-KCl) generally within 1°C. The method can be used to test whether waters of known composition, such as formation waters, could be the same as fluids trapped in inclusions in minerals in contact with these waters. The effect of dissolved CO_2 in lowering freezing points also can be calculated. (Authors' abstract)

PROKOF'EV, V.Yu. MIRONENKO, M.V., DOROFEYEVA, V.A. and **NAUMOV, V.B.,** 1989, Solubility of galenite in chloride solutions with high concentration of CO_2 and H_2S: Geokhimiya 1989, no. 4, p. 532-540 (in Russian, English abstract).

By computer calculations of heterogeneous mineral equilibria in the system NaCl-$MgCl_2$-$CaCl_2$-CO_2-CH_4-H_2S-H_2O, it has been determined that hydrothermal solution with concentrations of 1M NaCl, 1.4 M $MgCl_2$, 0.1 M $CaCl_2$, 5 M CO_2 and 10^{-2} M H_2S at 300°C (that corresponds to composition of ore-forming fluids and the formation conditions for Zyryanovskoe sulfur-ore base-metal deposit, Rudny Altai) can dissolve lead down to concentration of 10^{-3} M Pb. The main factor of ore deposition from this solution is increase of pH. Decrease of T and Cl content in the solution are less effective factors of Pb deposition. (Authors' abstract)

PROKOF'YEV, V.Yu., MIRONENKO, M.V., DOROFEEVA, V.A. and **NAUMOV, V.B.,** 1988, Degassing as a factor in precipitation of lead from chloride solutions of high CO_2 and H_2S concentrations: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 10 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci., Moscow, U.S.S.R.

Calculations and experimental data using ore-forming solutions of NaCl, $MgCl_2$, $CaCl_2$ with CO_2, CH_4 and H_2S, at 300°C indicated that P decrease and pH increase caused PbS precipitation. (A.K.)

PROL-LEDESMA, R.M. and **BROWNE, P.R.L.,** 1989, Hydrothermal alteration and fluid inclusion geothermometry of Los Humeros geothermal field, Mexico: Geothermics, v. 18, no. 5, p. 677-690. First author at Inst. de Geofisica and DEPFI, UNAM., Cd. Univ., Coyoacan 04510, Mexico.

The Los Humeros geothermal field, located in Puebla State, Mexico, occurs in a caldera; drillholes to 3000 m depth encountered a sequence of Quaternary lavas and pyroclastic rocks that range in composition from rhyolite to basalt but are dominantly andesitic. These rest upon the local basement comprising limestone and siltstone of Cretaceous age, which was encountered below 2500 m in the northern part of the field and 1000 m in its southern part.

Examination of 29 cores, mostly from below 900 m depth, from 14 wells show that the hydrothermal minerals that occur in the volcanic host rocks include quartz, calcite, epidote, amphibole, sericite, smectite, illite, chlorite, biotite, pyrite and hematite. Their distribution mainly reflects the prevailing hydrological and thermal regime where T locally exceed 300°C. The limestone basement rocks, however, have altered to an assemblage that includes calcite, quartz, wairakite, garnet, wollastonite, parawollastonite, sericite and fluorite.

Th of 356 fluid inclusions were measured and Tm ice of 200 determined. All except two sets of inclusions homogenized into the liquid phase and neither dms nor a clathrate phase were seen. The Th mostly match measured bore T that range from 250 to 360°C and the apparent salinities are from 0.2 to 2.7 wt % NaCl eq., but some contribution to freezing point depression by CO_2 is likely.

A preliminary model for the hydrology of the field based upon the hydrothermal alteration mineralogy and fluid inclusion data suggests that dilute hot water ascends via faults in the Central Caldera collapse area of the field and moves laterally outward to elsewhere within the caldera. (Authors' abstract)

PROL-LEDESMA, R.M. and **MacFARLANE, A.,** 1989, Fluid inclusion evidence for evolution of mineralising fluid in the Hualgayoc District, Peru, *in* P.R.L. Browne and K. Nicholson (eds.), Proc. 11th New Zealand Geothermal Workshop: Geothermal Inst., Univ. Auckland, p. 155-158. First author at Geothermal Inst. and Geology Dept., Auckland Univ., Auckland, New Zealand.

Microthermometric techniques were applied to samples from mantos and veins in the Hualgayoc District, Peru. Mineralisation in the district is hosted mainly in rocks from the Hualgayoc group (Mesozoic marine sedimentary and volcanic rocks). P and S inclusions in sphalerite and gangue minerals were examined petrographically and their Th and Tm (ice) measured. Three stages of sphalerite, with intermittent deposition of quartz, calcite and rhodocrosite are recognized. The results indicate that mineralisation took place at ~150°C to >350°C; the lowest values corresponding to vein mineralisation and the highest to the mantos. The highest apparent salinity values were observed in the manto samples (more than 16% eq. wt NaCl) in contrast to lower salinities (4.3% eq. wt NaCl) measured in one sphalerite sample from the San Filipe Vein. From the Los Mantos area to the north and the east, a trend of decreasing T and salinity exists. No evidence of boiling was observed in the sphalerite samples; however, boiling may have occurred during deposition of quartz and rhodocrosite in the veins. (Authors' abstract)

PUGIN, V.A., 1988, Liquid immiscibility in acid magmas: Geokhimiya, no. 5, p. 698-704 (in Russian; translated in Geochem. Int'l., v. 25, no. 12, p. 78-84, 1989). Author at Vernadskiy Inst. of Geochem. and Analy. Chem., USSR Acad. Sci.

Simulation results are presented for liquid immiscibility in a dacite-rhyolite magma at 5 kbar; experiments show that a dry magma containing 3-4% H_2O[sic] shows unmixing with the formation of liquids that model the trachyte-liparite unmixing in acid magmas. This immiscibility in a dry magma differs from that in one containing water in that one of the liquids of the "dry" magma accumulates many of the heavy elements, thus simulating a mineralization mechanism. (Author's abstract)

PURTOV, V.K., KHOLODNOV, V.V., ANFILOGOV, V.N. and **NECHKIN, G.S.,** 1988, The role of chlorine in the formation of magnetite skarns: Geologiya rudnykh mestorozhdeniy, 1988, no. 6, p. 24-34 (in Russian; translated in Int'l Geol. Rev., v. 31, p. 63-71, 1989). Authors at Inst. Geology and Geochemistry, Urals Scientific Center, USSR Academy of Sciences, Sverdlovsk, U.S.S.R.

The authors find that the Fe is carried mainly in acid chloride solutions and is deposited where these solutions are neutralized by carbonate rocks or alkaline solutions. The Cl contents of minerals, particularly apatite, are a guide to igneous complexes favorable for skarn deposits. (Authors' abstract)

PÜTTMANN, W., MERZ, C. and **SPECZIK, S.,** 1989, The secondary oxidation of organic material and its influence on Kupferschiefer mineralization of southwest Poland. Applied Geochem., v. 4, p. 151-161.

QING, Hairuo and **MOUNTJOY, Eric**, 1989a, Dolomitization of Middle Devonian Presqu'ile barrier at Pine Point: An indication of open-system diagenesis (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-64. Authors at Dept. Geol. Sci., McGill Univ., Montreal, PQ, H3A 2A7.

Four types of dolomites are recognized in the Middle Devonian Presqu'ile barrier at Pine Point: fine/medium crystalline (FMCD); medium crystalline (MCD); coarse crystalline (CCD); and saddle (SD). The spatial distribution of these dolomites and diagenetic paragenesis suggest that these dolomites occurred at least in 3 stages. FMCD is restricted in the back-barrier facies of the Muskeg Formation and probably formed penecontemporaneously from evaporitic brines. MCD is most abundant in the lower part of the barrier (Pine Point Formation). Later, a period of solution and fracturing occurred in the immediately overlying Sulfur Point Formation. CCD and early phase of SD (Presqu'ile) occurred in and adjacent to this new and higher conduit system and extended, across the Watt Mountain unconformity, into the lower part of the Slave Point Formation. Later more SD and MVT minerals were precipitated in this higher conduit system. Thus the Presqu'ile dolomite (CCD and SD) did not form in a mixing zone as previously interpreted, but formed during intermediate burial. This is supported by: petrographic data (CCD postdating stylolites); C and O isotopes (avg. $\delta^{18}O$ -7.9 and -8.1; $\delta^{13}C$ +1.4 and +1.2; for CCD and SD respectively); FI (90-100°C for SD); and Sr isotopes. Clearly all 3 stages were open diagenetic systems because of the enormous volumes of fluids required for dolomitization. This conduit system extends down dip for 400 km to NE B.C., and has remained open until the present. (Authors' abstract)

QING, Hairuo and **MOUNTJOY, Eric**, 1989b, Origin of dissolution vugs and breccias in Presqu'ile barrier (Middle Devonian) at Pine Point: Meteoric or hydrothermal karst? (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A9. Authors at Dept. Geological Sciences, McGill Univ., 3450 University St., Montreal H3A 2A7, Canada.

MVT deposits in Pine Point are closely associated with dissolution vugs and breccias, which are commonly interpreted to be related to meteoric karst systems. The associated closely crystalline saddle dolomites were suggested to have formed in a meteoric-seawater mixing zone environment.

Data from Pine Point area and 30 widely spaced wells in the Presqu'ile barrier in the adjacent subsurface indicate that: (1) the influence of meteoric water during the Watt Mountain exposure was limited because pendant cements extend only 12 m below the unconformity; (2) the extent of dissolution and brecciation associated with the unconformity in the subsurface Presqu'ile barrier is local when compared to Pine Point; (3) the "meteoric calcite line" was not observed in the Presqu'ile carbonates; and (4) the spatial distribution of S dissolution vugs and breccias is not controlled by the unconformity, but instead is closely associated with occurrences of saddle dolomites which cut across the unconformity. Isotopes and fluid inclusions indicate that saddle dolomites precipitated from hypersaline brines at ~100°C. Therefore the associated dissolution vugs and breccias must have formed in the subsurface by hydrothermal brines. The later hydrothermal dolomitization and karsting have almost completely overprinted and obliterated the earlier unconformity related meteoric solution system. (Authors' abstract)

QIU, Hua-ning and **DAI, Tong-mo**, 1989, $^{40}Ar/^{39}Ar$ technique for dating the fluid inclusions of quartz from a hydrothermal deposit: Chinese Sci. Bull. (Kexue Tonghau), v. 34, no. 22, p. 1887-1890 (in English). Authors at Institute of Geochemistry, Academia Sinica, Guiyang 550002, P.R.C.

In some hydrothermal deposits no K-rich minerals can be selected, and it is very difficult to determine the minerogenetic age by the traditional K-Ar method. In this study, the paragenous muscovite and quartz from Lushui tungsten deposit, western Yunnan, have been analysed by the $^{40}Ar/^{39}Ar$ technique. The aim of the work was to investigate the possibility of dating the inclusions in the quartz by the $^{40}Ar/^{39}Ar$ method, and sensible results were obtained. (Authors' abstract)

QUILEZ, E., SIERRA, J. and **VINDEL, E.**, 1989, A fluid inclusion study and genetic model of wolframite-bearing quartz veins, Garganta de los Montes, Spanish Central System (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 76. Authors at Dto. Crystal. y Mineral., Fac. de Ciencias Geol., Univ. Complutense, 28040 Madrid, Spain.

Wolframite-bearing quartz veins from Garganta de los Montes, Madrid province, are hosted by banded gneisses that have undergone intense migmatization. The ore deposit is genetically related to the La Cabrera granite batholith. The veins strike N75° and dip 75°S. The mineral association includes wolframite, quartz and minor amounts of scheelite, sphalerite, chalcopyrite, pyrrhotite, stannite and marcasite.

The fluid phases associated with quartz from the vein margin (early barren quartz) and from the vein center (late wolframite-bearing quartz) have been studied using microthermometry, scanning electron microscopy and crushing test analyses. Four hydrothermal stages have been distinguished: The earlier fluids, only recognized in the barren quartz, contain brine dp (halite) and trapped minerals. The second hydrothermal stage is characterized by complex-carbonic aqueous inclusions of low salinity (3 to 7 wt % NaCl eq.) and low density (0.4 to 0.7 g/cm^{-3}). They homogenize mainly to liquid and sometimes to vapor between 300° and 420°C. The third stage is represented by low to moderate salinity inclusions (<9 wt % NaCl eq.) of moderate density (0.8 to 0.96 g/cm^{-3}), Th between 120° and 330°C. The late fluids correspond to aqueous solutions of higher salinities (H_2O-NaCl with Ca^{2+} and Mg^{2+}) and densities (>1 g/cm^{-3}) which were trapped at Th ranging between 50° and 130°C. The role played by the complex-carbonic aqueous fluids in the transport and precipitation of W is suggested in this paper. (Authors' abstract)

QUON, D.H.H., WANG, S.S.B., TORRIE, G. and WHEAT, T.A., 1989, Crystallization of zirconium oxide under hydrothermal conditions (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-117. Authors at CANMET, Energy, Mines and Resources Canada, Ottawa K1A 0G1, Canada.

Zirconia-based ceramic materials have potential applications in high T furnace insulation, hot extrusion and casting dies, P nozzles, cutting tools, engine parts and electronic materials. High purity and superfine powders of zirconium oxide (baddelyite) were synthesized from a solution containing zirconium oxychloride and urea under hydrothermal conditions. Crystallization of the metastable tetragona zirconia using yttrium oxide and magnesium oxide as stabilizing agents was successfully achieved. The mechanism of hydrothermal reaction to produce these powders will be presented. (Authors' abstract)

RAJU, K.U.G. and ATKINSON, Gordon, 1989, Thermodynamics of "scale" mineral solubilities. 2. $SrSO_4(s)$ in aqueous NaCl: J. Chem. Eng. Data, v. 34, p. 361-364.

RAMBOZ, C.C., 1989, Conditions of fluid circulation in rift environments: Comparison between the Sub-alpine Basin and the Central Red Sea (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 77. Author at CNRS/CRPG, BP 20, 54501 - Vandoeuvre-lès-Nancy, France.

The comparison of the formation conditions of Pb-Zn mineralization at Les Malines (LM, margin of the Sub-alpine Basin SB, France) and in Atlantis II Deep (AII, Red Sea) allows one to identify the characteristic mechanisms of fluid circulation and sulphide deposition in rift environments. (a) FI in dolomite (SB) and anhydrite (RS) coexisting with sulphides, yield constant composition-variable volume patterns. These indicate intermittent brine influxes and isochemical cooling at the deposition site. Transient fluid migration was related to the catastrophic dewatering of sediments in the deep basin at LM and to geysering (i.e., abrupt destabilization of the water column due to boiling) in AII. (b) Fluid mixing neither occurred at LM nor in AII because metals were deposited below seals (Triassic shales and stratified brines respectively), which prevented the influx to the deposition site of oxidizing waters, of meteoric or sea water origin. (c) There are abundant isotopic evidences that, in both cases, the mineralizing fluids originated (at least partly) laterally from impermeable sediments (shales or clays) deposited in the deep basin during early rifting. (d) Rapid adiabatic centripetal or centrifugal fluid migration preferentially occurred along ancient reactivated basement fractures parallel to σ_3, both at LM and in AII. Hence it is concluded that geopressured fluids are preferentially released along transform directions in rift environments. (e) K/Ar dating of clays associated with sulphides in the SB margin and interpretative models of the present day Central Red Sea suggest that fluid dewatering (and hence seismic activity) along transform faults was in both cases contemporaneous with a change in the mechanism of accretion. A similar interpretation was proposed for the Portuguese continental margin during historic times. (Author's abstract) (Eight references deleted. E.R.)

RANAWAT, P.S. and **SHARMA, N.K.,** 1989, Petrology of the Precambrian lead-zinc deposit, Rampura-Agucha, India (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-666. First author at Sukhadia Univ., Udaipur, India.

The Precambrian formations of central Rajasthan host a unique lead-zinc deposit near Rampura-Agucha. Fluid inclusion data of quartz and tourmaline from the pegmatite shows that the pegmatite was emplaced at a much later stage in the area. These minerals contain CO_2, $CO_2 + H_2O$ and aqueous inclusions which indicate low P-T conditions of their formation (640 bars, 300°C).

On the basis of field evidences, petrography, petrochemistry and nature of mineralization, it is concluded that the Rampura-Agucha Pb-Zn deposit represents a synsedimentary metamorphosed type of deposit. (From authors' abstract by E.R.)

RANKIN, A.H., 1989, Fluid inclusions: Geology Today, Jan-Feb. 1989, p. 21-24.

FI in crystals provide a valuable insight into the nature and origin of ancient mineral-forming fluids. FI are established geothermometers and geobarometers, but their use as chemical indicators has in the past been hampered by their extremely small size. With the rapid development of a range of modern instrumental microanalytical techniques it is becoming increasingly possible to determine in detail the compositions of various phases present within minute inclusions down to the parts-per-million level. (Author's abstract)

RANKIN, A.H. and **HODGE, B.L.,** 1989, Exceptional oil-bearing inclusions in fluorite from Baluchistan, Pakistan (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 78-79. First author at Imperial College, London SW7 2BP, UK.

Phenomenally large (up to 2 mm) oil-bearing and associated brine inclusions in fluorite from carbonate-hosted epigenetic fluorite-calcite-(barite) deposits of the Koh-e-Maran area of Baluchistan, Pakistan, were investigated using a combination of microthermometry, UV-microscopy, FT-IR microspectroscopy and gas chromatography.

The liquid hydrocarbon phase in two-phase liquid-vapor 'oil' inclusions is brown in color. It fluoresces bright-yellow under UV light and emits a distinctive "kerosene" odor on crushing. FTIR spectroscopy and GC analysis confirm the dominance of saturated, low molecular weight, aliphatic hydrocarbons in the inclusions (with a small quantity of CO_2). All the inclusions appear P and are characteristically ovoid, tear-drop, and bottle-shaped. Th of the oil and coexisting vapor bubble range from 96 to 108°C. The hydrocarbon and brine components in mixed inclusions failed to homogenize even at T > 200°C. Coexisting P aqueous inclusions homogenize at slightly higher T (mean 112°C). These T are similar to those recorded for a later generation of aqueous inclusions (mean 110°C) but the earlier inclusions may be distinguished on the basis of their higher Te and Tm ice.

Two types of mixed aqueous and 'oil' inclusions occur. In water/oil types the aqueous phase is dominant; it "wets" the oil and exhibits Tm ice similar to P type A inclusions. Such inclusions are clearly P and represent coeval trapping of immiscible drops of oil in brine during P growth. In oil/water inclusions the oil is dominant and appears to 'wet' the aqueous phase resulting in an odd "dish-shaped" meniscus. Te of the aqueous phase occurs at ~-45°C. Tm ice = ~-10°C and a second, unidentified pale-yellow solid (complex gas clathrate?) melts abruptly at ~+1.7°C. The oil or liquid petroleum part of the inclusion appears P but the aqueous part is thought to represent a S infill caused by planes of S brine inclusions which commonly crosscut the samples. The FI evidence suggests that fluorite precipitated from a dilute (3.5 wt % NaCl eq.) oil field-type brine at ~110-130°C allowing for a few tens of degree 'P correction' in the presence of an immiscible liquid petroleum phase dominated by saturated, light hydrocarbons. This "oil" was probably present as an emulsion in the aqueous fluid and the phenomenally large size of the inclusions is thought to reflect the large droplet size in the emulsion.

Infiltration of a more saline, Ca-enriched brine into pre-existing oil inclusions resulted in complex oil-water inclusions showing a reversal in the nature and shape of the oil-water interface due to the presence of unspecified surfactants in the brine which affected the wetting characteristics of the oil.

The Th and the presence of liquid petroleum inclusions ar characteristic of MVT deposits in many other parts of the world and a basinal brine model can be invoked for the genesis of the Koh-e-Maran deposits. It is interesting to speculate that the absence of significance Pb and Zn mineralization in the area is as much due to the poor metal-carrying potential of low chloride brines as availability of metals in the source region. (Authors' abstract)

RASUMNY, J., 1989, Submicroscopic investigations (SEM) on fluid inclusions within minerals and rocks from Savoy (French Alps) (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-676-677. Author at Faculte des Sciences, Orsay, France. [Paper not presented at Congress. E.R.]

Since our contribution presented at the 27th session (IGC, Moscow 1984), scanning electron microscopy (SEM) of intra- as well as intergranular cavities within minerals within minerals follows a steady expansion, in first line in the French Alps. Such fractographic studies show fluid inclusions. Thus new aspects of the thermal/mechanical geological story of such alpine materials will be investigated at different scales. New results will be confronted with those already published, concerning Roc Tourné and Feug samples in the Haute-Savoie, as well as gangue materials of Notre-Dame-de-la-Gorge (Val Montjoie) and quartz veins from Col de Voza (Mont Black Massif) (CTHS, Bull. Sciences, VII, Paris, 1984). (Authors' abstract)

RAVENHURST, C.E., REYNOLDS, P.H., ZENTILLI, Marcos, KRUEGER, H.W. and **BLENKINSOP, John**, 1989, Formation of Carboniferous Pb-Zn and barite mineralization from basin-derived fluids, Nova Scotia, Canada: Econ. Geol., v. 84, p. 1471-1488. First author at Geology Dept., Smith College, Northampton, MA 01063.

Lead-zinc and barite deposits in central Nova Scotia generally occur at the Tournaisian-Visean (Mississippian) clastic carbonate-evaporite disconformity overlying Cambrian to Devonian metasedimentary and granitic rocks. The deposits are located at the southern margin of the >10 km-deep Carboniferous Maritimes (Fundy-Magdalen) basin.

Fluid inclusions Th of ore-stage to postore minerals range from 230° to 130°C and fluid salinity is ≥2.4 eq. wt % NaCl. A mineralization age of ca. 300 to 330 Ma is suggested by: (1) fission-trace dates on zircon from clastic host rock at Gays River; (2) K-Ar dates on clays from altered clastic rock in close proximity to mineralization; and (3) Rb-Sr data on illite from samples collected over a 10-m section of Tournaisian sandstone (far away from mineralization). Pb and Sr isotope data indicate that Tournaisian rock of the Horton Group could have been a source (at ca. 300 Ma) of Pb and radiogenic Sr in the ore-stage minerals at the larger deposits. Visean carbonate C and sulfate were the dominant sources of C and S, respectively. H and O isotope data suggest that the mineralizing fluids were basinal brines. Nonbiogenic sulfate reduction at the deposits is the likely sulfide precipitation mechanism.

The ore-forming fluids may have originated at a >5-km depth under Visean evaporites in the Magdalen basin and migrated rapidly through Tournaisian clastic rocks and the immediately overlying Pembroke breccia to the basin margins. A pulse of regional tectonism may have set off at least one massive, hydrofracturing, compaction-driven, fluid expulsion event by about 300 Ma. (Authors' abstract)

REDECKE, P. and **FRIEDRICH, G.**, 1989, Studies of genesis of the lead-zinc mineralization in southern Limburg (the Netherlands) and in northern Eifel (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 151 (in German) (supplementary issue to European J. Mineral., v. 1.).

At the eastern margin of the Brabantian massif, in the lower Carboniferous beds of clays and carbonates, there occurs vein-type mineralization consisting of quartz, pyrite, marcasite, sphalerite, wurtzite, calcite and galena. Pyrite contains sometimes up to 7% arsenic. Th of fluid inclusions in quartz is 125°C, Tm -17°C and Te -45 to -52°C. Calcite from borehole Albertsgrube near Stolberg from a Zn-Pb ore vein yielded Th 67 to 175°C, Tm -4°C (Th ca. 72°C), -12°C (Th ca. 153°C) and -20°C (Th ca. 171°C). The veins formed most probably by the intraformation substance redistribution. (From the authors' abstract translated by A.K.)

REED, M.H., 1989, Epithermal boiling with decreasing pH: Selective precipitation of gold and silver vs. base metal sulfides (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A350.

REIMER, G.M., 1989, Soil-gas helium: Four variations associated with earthquakes along San Andreas Fault in central California (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-685-686.

RENDERS, P.J. and SEWARD, T.M., 1989, The stability of hydrosulphido- and sulphido-complexes of Au(I) and Ag(I) at 25°C: Geochim. Cosmochim. Acta, v. 53, p. 245-253.

REUTEL, C., 1989, Fluid evolution in the KTB drilling area at the western margin of the Bohemian Massif (microthermometry and LRM) (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 80. Author at Inst. Geol. & Dynamik der Lithos., Goldschmidstr. 3, D-3400 Gottingen, FRG.

The [rocks] consist mainly of a series of disthene-sillimanite-bearing biotite-garnet gneisses and metabasites, with cataclasis of varying intensity. These cataclastic zones are characterized by quartz solution, chloritization and graphitization. The FI in the vicinity of the borehole contain CO_2, CO_2-CH_4($\pm N_2$) mixtures and aqueous inclusions of different composition.

In addition to the microthermometric and LRM studies on the FI LRM and TEM investigations were carried out on graphites in metacherts and cataclasites. By comparing the results with graphites of known formation T there is evidence of a formation T ~350°-400°C of graphites in the cataclastic zones of the pilot borehole and its vicinity. These T coincide with estimations based on FI data giving P/T conditions of about 2.5 kb and 380°C. It is assumed that the carbon is transported via fluid phase of CO_2-CH_4 whereas the cataclasis acts as a "tribochemical catalyst" to advance the reaction $CO_2 + CH_4 \rightarrow C + 2H_2O$. The CO_2-CH_4 and CO_2 inclusions are remnants of these fluid phases. The H_2O component of this reaction is consumed in chloritization.

A model P/T path of palaeoactive fluids in the ZEV is to be constructed with: (i) MP-metamorphic fluids (not preserved); (ii) metamorphic fluids, associated with metablastesis: low to high salinity, high T, gaseous inclusions >3 kb/500°C; (iii) fluids in connection with the magmatic thermal event, low to high salinity, gaseous inclusions, about 25 kb/380°C subsequently intense cataclases with formation of graphite and chloritization; and (iv) alteration and younger fluid events, highly saline ≤1 kb/200°C. (Abbreviated from the author's abstract by E.R.)

REUTEL, C. and **HORN, E.E.**, 1989, Evolution of H_2O-$NaCl$-CO_2-CH_4-bearing fluids in the pilot borehole of the continental deep drilling programme (FRG) and its vicinity: First results (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 54. Authors at Inst. Geol. and Dynamnik der Lithosphäre der Georg-August-Univ., D-3400 Göttingen, Goldschmidt str. 3, FRG.

In order to determine palaeofluids and palaeofluid passages in connection with the continental deep drilling KTB systematically, an analytical line comprising various methods (microthermometry, Raman spectroscopy, SEM-CL, optical CL [cathodoluminescence], decrepitometry) has been designed at the IGDL Göttingen. By combining these methods the evolution of the fluid systems occurring in the pilot borehole and its vicinity is to be reconstructed.

In the investigation area (zone of Erbendorf-Vohenstraustrasse) a series of disthene-sillimanite-bearing biotite-garnet-gneisses occurs which in the pilot borehole are cataclastic along the entire cored depth down to 3000 m. These cataclastic zones are characterized by quartz solution, chloritization and graphitization. The degree of cataclasis can be made visible by optical Cl and SEM-CL down to the µm scale. The FI occurring in the pilot borehole and its vicinity contain CO_2, CH_4-CO_2 and aqueous solutions of different composition ($NaCl$, $CaCl_2 \pm MgCl_2 \pm KCl$) and density.

The isochore constructions provide evidence of post-peak metamorphic fluid evolution. From the occurrence and relative position of the fluid phases a PT path is tried to be inferred, beginning with CO_2 inclusions (ρ = 0.94 g/cc) through high- to medium-T H_2O (Tt 530-300°C), CO_2 (ρ = 0.86 - 0.78 g/cc), CH_4-CO_2 and finally highly saline aqueous fluids. Cogenetic H_2O and CO_2 inclusions with formation conditions of 2.5 kb and 380°C provide a step in the course of retrograde evolution.

By SEM-CL investigations cracking structures could be made visible in this sample, which originated from natural decrepitation and reequilibration of the fluids under the physico-chemical conditions prevailing at that time.

The CH_4-CO_2 inclusions during evolution can be directly connected with the graphitization and chloritization of cataclasites in the pilot borehole. These trapped phases possibly originated in the graphite occurrences produced through prograde metamorphism, which were gasified through H_2 out of radiolysis of H_2O. With changing geochemical and P/T conditions graphite is precipitated out of the CO_2-CH_4 fluids. H_2O released in the process is consumed in the formation of chlorite which occurs parallel-intergrown with graphite. Analyses of chlorites in the adjacent geothermal well PHllersreuth provided formation T of 270°-290°C (Friedrich et al., in prep.), first Raman spectroscopic investigations evidence that the graphites possibly formed in a similar T range.

The highly saline fluids with divalent cation contents are the last stage of formation to be evidenced by fluids at T of ~170°C and possibly originate in altered neighboring rock. (Authors' abstract)

REYES, A.G., 1989, Cooling in Philippine geothermal systems: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 573-576. Author at Philippine Nat'l Oil Co.-Energy Development Corp., Geothermal Div., Manila, Philippines.

In four of the the geothermal fields studied: Tongonan in Leyte, Palinpinon in Negros, Bacon-Manito in Albay-Sorsogon, and Mt. Apo in Cotabato, cool, dilute, sometimes oxygenated meteoric fluids apparently penetrate down to a maximum of 2700 m at the margins of the system and 1300 m near the upflow regions, by way of structures. Evidences for cooling are based on key hydrothermal minerals, fluid inclusion data, measured well T and sometimes, downhole fluid chemistry. (Author's abstract)

REYES, A.G. and CARDILE, C.M., 1989, Characterization of clay scales forming in Philippine geothermal wells: Geothermics, v. 18, no. 3, p. 429-446. First author at Philippine Nat'l Oil Co., Geothermal Div., Fort Bonifacio, Metro Manila, Philippines.

Smectite scales occur in 24 out of the 36 blocked wells located in Tongonan, Palinpinon and Bacon-Manito. These comprise 2-85% of the well scales and form at depths at 33-2620 m, where measured and fluid inclusion temperatures [in anhydrite] are 40-320°C. Most, however, occur below the production casing shoe where T are ≥230°C, often at depths coinciding with aquifers. The clay scales are compositionally and structurally different from the bentonite used in drilling, which is essentially a sodium-rich montmorillonite. The clay deposits are expanding, generally disordered, and combine the characteristics of a montmorillonite, saponite and vermiculite in terms of reaction to cationic exchange treatments, structure and composition. six types of clay scales were identified, but the predominant one, comprising 60-100% of the clay deposits in a well, is Mg- and Fe-rich and referred to as a vermiculitic species. The crystallinity, degree of disorder, textures, optical characteristics, structure and relative amounts of structural Al, Mg and Fe vary with time, T and fluid composition, but not with depth and measured P. Despite its variance from bentonite characteristics, one of the dominant suggested mechanisms for clay scale formation uses the drilling mud in the well as a substrate, from which the Mg- and Fe-rich clay evolves. Another important possible mechanism for formation of the clay scale is the precipitation of the clays from hydrothermal fluids, wherein Mg and Al appear to be the limiting elements. Other, less important, mechanisms of formation are: alteration of chloritized cuttings in the well to the vermiculitic species and the probable introduction of smectite from the formation. (Authors' abstract)

REYF, F.G., SERYKH, V.I. and KANAKIN, S.V., 1989, Formation conditions of topaz-bearing biotite-albite granites of Akchatau: Doklady Akad. Nauk SSSR, v. 306, no. 4, p. 953-956 (in Russian).

Granitic massif Akchatau is a representative of ore-bearing intrusions, formed in several intrusive phases, including vein formations. One of the vein generations consists of topaz-bearing biotite-albite granite veins. One vein in its central part bears subhedral topaz crystals up to 1.5 cm in width. This topaz contains solid inclusions of all the rock-forming minerals from the vein, and hence is the latest mineral. Quartz phenocrysts bear numerous melt inclusions and tiny accompanying fluid inclusions, distributed uniformly or in concentric growth zones. This indicates the quartz crystallization from a fluid-saturated melt. Topaz contains also both above-mentioned inclusion types. Melt inclusions contain two-phase (at room T) fluid and a crystal aggregate with major phases of quartz and muscovite; Th ranges from 670 to 640°C (98 measurements); microprobe analyses of the homogenized inclusions are given. Accompanying fluid inclusions are rare in central parts of the crystals and numerous in the outer zones. Fluid inclusions in quartz always homogenize in liquid phase (Th 355-230°C), but in topaz both in gas and in liquid phases (Th 420-460°C). The subsequently occurring topaz growth layers 50-400 µm thick bear inclusions homogenizing either solely in liquid or in gas; central topaz parts bear melt and mainly gas-homogenizing inclusions, the layers containing the liquid-homogenizing are very rare, but the latter prevail in outer parts of the topazes. G- and L-homogenizing inclusions occur in one layer only exclusively, and their Th are comparable with Th of melt inclusions. During topaz crystallization the magmatic fluid had a near-critical density and due to the P fluctuations either it was above or below the critical isochore, sometimes going down to the G + L field. NaCl concentrations ranged in L phase from 26 to

15%, P were estimated to be 450 to 90 bar. Every new portion of melt coming from the magmatic chamber was richer in water and started to crystallize at lower T, suggesting the existence of crystal fractionation in the magma chamber. (A.K.)

RIBERA, F., AYORA, C. and CARDELLACH, E., 1989, Gold-arsenopyrite remobilization in the Vall de Ribes, eastern Pyrenees, Spain: Geochemical aspects (abst.): Terra abstracts, v. 1, p. 16.

The lower part of the Cambro-Ordovician series of Vall de Ribes contains syngenetic Au-bearing arsenopyrite dissemination in chlorite schists. Higher amounts of ore can be found as epigenetic mineralizations, formed by remobilization during Hercynian greenschist metamorphism and contemporaneous as well as later Alpine deformation events.

Fluids responsible for remobilization were initially CO_2-rich evolving to CO_2-free brines of about 9% NaCl + 5% $CaCl_2$ + 1% KCl, circulating between 420 and 350°C and 2 kbars. Fe-Mn-SiO_2 metasomatism in enclosing dolomites is restricted to a few meters from quartz mineralized veins, and it is not a useful prospecting tool. On the contrary, C-O isotope ratios in dolomites show a pervasive circulation of fluids through the whole volume of rocks and seem to be a good tracer of fluid flow through the metasediments. (Authors' abstract)

RICHARDS, H.G., CANN, J.R. and JENSENIUS, J., 1989, Mineralogical zonation and metasomatism of the alteration pipes of Cyprus sulfide deposits: Econ. Geol., v. 84, p. 91-115. First author at Camborne Sch. Mines Geother. Energy Project, Rosemanowes Quarry, Herniss, Penryn, Cornwall TR10 9DU, UK.

The stockwork mineralized lavas associated with the cupriferous pyrite deposits of Cyprus occur in the cores of concentrically zoned alteration pipes. These represent the channels of ascending hydrothermal solutions. This paper reports a detailed mineralogical and geochemical study of the [alteration at the] Pitharokhoma alteration pipe and reconnaissance studies of other pipes. (From authors' abstract by E.R.)

Th was determined for five samples of quartz (Table 6); they range from 276-349°C. (E.R.)

RICHARDS, J.P. and SPOONER, E.T.C., 1989, Evidence of Cu-(Ag) mineralization by magmatic-meteoric fluid mixing in Keweenawan fissure veins, Mamainse Point, Ontario: Econ. Geol., v. 84, p. 360-385. First author at Research School of Earth Sciences, Australian Nat'l Univ., GPO Box 4, Canberra, ACT 2601, Australia.

Locally rich (up to 40% Cu) Cu-(Fe) sulfide mineralization with minor Ag occurs in fault-related fissure veins cutting, but probably penecontemporaneous with, Keweenawan plateau basalt lava flows at Mamainse Point, Ontario. Paragenetic studies of samples from the Coppercorp mine define four stages of mineralization: (1) early pyrite-(chalcopyrite) with strong silicification and sericitic alteration; (2) a transitional stage of chalcopyrite-hematite and bornite-hematite assemblages, with propylitic alteration; (3) main-stage chalcocite-hematite, often replacing earlier sulfides, with propylitic alteration; and (4) late-stage, low-T calcite deposition, with local Cu°, Ag°, Cu arsenides, and cuprite. This paragenetic sequence suggests an increase in fO_2, perhaps accompanied by an increase in pH and a decrease in total sulfur activity.

The mineralized fissures crosscut but are coeval with regional-scale low-grade (zeolitic to local epidotic) alteration in the plateau basalt sequence; their mineralogy, particularly the early sericitic wall-rock alteration, is at variance with the regional alteration mineralogy. This contrast is supported by FI and light stable isotope data [C,O]. T of the regional alteration reached little higher than 300°C at the base of the lava pile, and fluid salinities were generally below ~2 eq. wt % NaCl, suggesting the dominant presence of meteoric water. However, in the fissure veins, fluids varied from <200°C and <2 eq. wt % NaCl, to ≥450°C and ~22 eq. wt % NaCl. FI representing the hot saline fluids were only found in the presence of Cu mineralization, and it is therefore concluded that these fluids were responsible for metal transport. Analysis of decrepitation residues from FI in chalcocite indicate that the fluids were dominantly NaCl-$CaCl_2$-H_2O solutions; suppression of the critical curve by the presence of Ca^{+2} permits the interpretation that these saline, high-T fluids were near their critical point at ~450°C. Their high T compared to the ambient fluids suggest that they were derived from below the Keweenawan lava pile and that they may have been associated with intrusive magmatic activity. Approximately positively correlated arrays of Th vs. salinity data from FI in ore samples suggest that mixing between the hot saline fluid and the cooler meteoric ground waters was an important mechanism for deposition of Cu-(Fe) sulfides. The combined effects of rapid cooling, dilution, neutralization, and oxidation resulting from this process would cause a significant drop in Cu solubility with consequent deposition of ore; this process would also explain the observed paragenetic sequence of reduced to oxidized assemblages.

The range of $\delta^{18}O$ from magmatic to lighter values in the mineralized veins suggests that meteoric water was also present during ore deposition and was mixed in varying proportions with a magmatic fluid. The isotopic data, therefore, support a model of meteoric ground water and magmatic (or highly exchanged) fluid interaction in the fissure veins.

Comparisons are made to the nearby Keweenawan Jogran Cu-(Mo) porphyry, and the Tribag Cu-(Mo) breccia pipes. Similarities between these deposits and the Mamainse Point fissure veins in mineralogy, fluid properties, and light stable isotope compositions suggest a genetic link. (From authors' abstract by E.R.)

RIDLEY, W.I., PERFIT, M.R. and JONASSON, I.R., 1989, Progressive alteration and base metal mineralization of MORB from the Galapagos Rift: A detailed geochemical study (abst.): Eos, v. 70, p. 1397.

RIEKEN, Ralf, 1988, Fluid composition and migration processes in paleo-fluid systems in sedimentary rocks of the North German basin (microthermometry, Laser-Raman spectroscopy and isotope geochemistry): Göttinger Arb. Geol. Paläont., v. 37, 116 pp. (in German, English abstract).

Microthermometric studies on fluid inclusions in sandstones and Zechstein carbonates from the North German basin have shown that the fluid inclusions in the syndiagenetic cements can be differentiated based on the paleo-T. An increase in the formation T of the fluid inclusions with increasing depth can generally be detected. The formation T of the fluid inclusions in quartz overgrowths and carbonate cements in the sandstones northeast of Hannover are indicative of elevated heat flow. In the Upper Carboniferous sandstones of the North German basin, CH_4-bearing fluid inclusions were found. Raman probe studies on the methane inclusions yielded pure methane, in several cases with admixtures of ethane and isomeres of the alkane group. Three phases of quartz cements have been identified using cathodoluminescence. In contrast to the sandstone samples, the fluid inclusions in the Zechstein carbonates show no change in salinity with increasing depth. (Author's abstract)

RILEY, G.N., Jr. and KOHLSTEDT, D.L., 1989a, Melt infiltration in an olivine-melt system: The influence of rock porosity (abst.): Eos, v. 70, p. 502. Authors at Dept. Materials Sci. and Engrg., Cornell Univ., Ithaca, NY 14853.

Experiments have been conducted in an olivine-melt system to determine the influence of rock porosity on the kinetics of melt infiltration. Melt infiltration couples were formed between fully dense, K glass discs and polycrystalline San Carlos olivine discs with two different initial porosities. The experiments were conduced in a gas-medium P vessel at 1300°C and a confining P of 300 MPa for 1.25, 3, 4, and 12 hours. The melt fraction as a function of distance into the olivine disc was determined from K X-ray maps acquired with a wavelength dispersive spectrometer on a JEOL 733 Superprobe. Because K partitions almost entirely into the melt phase, the resulting X-ray maps give a quantitative representation of the melt fraction-distance relationship. The results of the experiments indicate that rock porosity significantly influences the amount of melt infiltration. Specifically, the amount of melt which has infiltrated into the olivine disc is increased by a factor of 2 when the rock porosity is decreased from ~1.5% to 0.5%. (Authors' abstract)

RILEY, G.N., Jr. and KOHLSTEDT, D.L., 1989b, Melt infiltration in a synthetic and a natural melt-olivine system: The influence of H_2O and CO_2 (abst.): Eos, v. 70, p. 1416.

RINK, W.J. and ODOM, A.L., 1989, Giant radiation-damage halos in quartz: Geology, v. 17, p. 54.

RIYAZULLA, M.S. and **PATHAN, A.M.**, 1989, A metamorphic model for the Hutti gold deposit of Hutti greenstone belt, Dharwar craton, India (abst.): Terra abstracts, v. 1, p. 30-31.

The devolatilization of mafic rocks generated low salinity near neutral H_2O-CO_2 metamorphic fluids carrying Au as reduced sulphur complexes, which were channeled towards suitable structural sites, and Au was deposited as a result of decrease in solubility and fluid wall rock interaction.

The field, structural, petrographic, and fluid inclusion studies are found to be compatible with a metamorphic model for the genesis of Hutti Au deposit. (From authors' abstract by E.R.)

ROBB, L.J., CATHELINEAU, M., LANDAIS, P., DUBESSY, J. and **BAILLY, L.**, 1989, The nature of late stage fluids affecting the Witwatersrand conglomerates: Fluid inclusion and mineralogical data (abst.): Abstract no. 3/12/P, Abstracts Volume, Gold 89 in Europe, Toulouse, France, Blackwell Sci. Publications, London. See also similar item in Terra abstracts, v. 1, p. 31. (E.R.)

The Witwatersrand Basin constitutes a thick sequence (c. 10 km) of clastic sediments that have been affected by a regional greenschist facies of metamorphism. Prodigious concentrations of Au are located in conglomerates and developed on unconformity surfaces, particularly in the upper half of the sedimentary pile. The origin of mineralization has been much debated in the past with contrasting ideas fluctuating between placer and hydrothermal (especially the role of post depositional processes on Au mineralization, Phillips et al., 1988) points of view. Post depositional fluid activity is demonstrated for example by the numerous phases of quartz veining that occasionally cross-cut the conglomerates. Systematic fluid inclusion studies carried out on quartz vein samples from the vicinity of the Ventersdorp Contact Reef and Basal Reef at the Deelkraal and Free Gold mines, respectively, demonstrate the existence of two types of fluids.

H_2O-NaCl fluids: In quartz veins from F.S.G., two-phase (L+V) inclusions dominate and are characterized by salinities ranging from 5.5 to 8.5 wt % eq NaCl, and Th (L) in the range 130-170°C. At Deelkraal, higher salinities have been recorded in the range 12.5-15.5 wt % eq NaCl, while their Th are somewhat lower (110-150°C).

CH_4-C_2H_6-H_2-(N_2) fluids: The organic inclusions occur in the Deelkraal quartz veins, as single phase (V) inclusions at 25°C and have Th(V) between -75°C and -90°C. Fluids consist dominantly of CH_4 (>95%) with significant amounts of C_2H_6, molecular H_2, and N_2 traces (Raman spectrometry). Such gases may originate from the radiolysis of organic matter associated with a high tenor of uranium (up to 12 wt %).

These results confirm the fact that complex fluid [s] circulated through the Witwatersrand sediments at some stage associated with, or subsequent to, diagenesis. Although these fluids clearly remobilized sulphide phases, it is not yet apparent whether either of these fluids were associated with Au remobilization or not. (Authors' abstract)

ROBERTS, Stephen, SANDERSON, Dave, GUMIEL, Pablo and **DEE, Stephen**, 1989, Tectonic and fluid evolution of auriferous quartz veins from the La Codosera area, S.W. Spain (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 8. First author at Dept. Geology, The University, Highfield, Southampton, U.K.

The La Codosera syncline [consists of] Cambrian-Devonian slates and quartzites which were affected by Hercynian ductile deformation, followed by late granite plutonism and faulting, and continued Mesozoic and Tertiary fracturing. Both margins of the syncline contain lode Au mineralisation associated with pyrite and arsenopyrite.

Preliminary fluid inclusion analyses indicate that the auriferous veins resulted from the passage of dilute (<4 wt % NaCl eq.) CO_2-rich fluid at 250-300°C. Additional volatiles, as yet unspecified (CH_4, N_2?), are also contained within the veins and notably increase in samples where sulphides are present. (From authors' abstract by E.R.)

ROBINSON, B.W. and **MERCHANT, R.J.**, 1989, Mineralisation, fluid inclusion and sulphur isotope studies of the Thames-Tapu area, Hauraki goldfield, New Zealand: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 589-592. First author at Institute of Nuclear Sciences, DSIR, Lower Hutt, New Zealand.

In the Thames-Tapu area the earliest (Cu-Bi-Mo-Au) mineralisation is found as quartz veins in pervasive, concentric alteration zones surrounding high level quartz diorite and dacite porphyry centres in Tertiary Coromandel Group andesites. Fluid inclusion studies and sulphur isotope mineral pairs indicate deposition ~400°C from boiling fluids. A later phase of quartz vein mineralisation (base metal and precious metal-telluride assemblages) occurs ~300°C. Sulphide $\delta^{34}S_{CDT}$ values average +2‰ and reflect a dominant H_2S source of magmatic origin. At Thames, a younger event probably related to U[pper]. Pliocene rhyolite volcanism produced argillic alteration and the famous bonanza-type precious metal deposits (Au-pyragyrite) in pre-existing structures. In the kaolinite alteration zone, acid conditions promoted sulphur isotope exchange: barite $\delta^{34}S$ values up to +25‰ and host rock pyrite values down to -3‰. The hydrothermal systems then operative appear similar to current geothermal areas of the circum Pacific. (Authors' abstract)

ROEDDER, Edwin and STALDER, H.A., 1989, "Pneumatolysis" and fluid-inclusion evidence for crystal growth from a vapor phase (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 55. First author at Dept. Earth and Planet. Sci., Harvard Univ., Cambridge, MA 01238.

The term pneumatolysis has been used for various geological environments, but the essential feature of most usage has been mineral formation from a hot fluid of low density. As an arbitrary limit, this density is here assumed to be ≤ 0.1 $gm \cdot cm^{-3}$. The best evidence for pneumatolytic conditions is found in the presence of vapor-rich inclusions, but considerable ambiguity remains and hence such evidence must be used with care. Many samples formerly thought to be of pneumatolytic origin were more likely formed from dense solutions that boiled or effervesced, but three examples of presumably valid vapor-phase crystallization in volcanic rocks are given. These are from Summitt Rock, Oregon, the Thomas Range, Utah, and the Wah Wah Mountains, Utah. The first consists of brilliant crystals of plagioclase and orthopyroxene projecting into lenticular cavities in an andesite plug; the second and third consist of topaz and red beryl crystals, respectively, in vugs and or fractures in rhyolite. All three are believed to have formed by diffusion of their "nonvolatile" constituents through a static low-density vapor phase, and hence are truly pneumatolytic. (Authors' abstract)

RONA, P.A. and SPEER, K.G., 1989, An Atlantic hydrothermal plume: Trans-Atlantic geotraverse (TAG) area, Mid-Atlantic Ridge crest near 26°N: J. Geophys. Res., v. 94, no. B10, p. 13,879-13,893.

ROSEN, O.M. and SONYUSHKIN, V.E., 1989a, Proterozoic collisional granites of the Anabar shield (North Siberia): Potential sources and P-T fluid regime (abst.): Geol. Surv. Finland Special Paper 8, p. 113. Authors at Institute of Lithosphere, Staromonetny per. 22, Moscow 109180, U.S.S.R.

The majority of the Proterozoic granites are located along fault belts 10-30 km wide and more than 200 km long. These belts were formed 1.9 Ga ago as suture zones of collision of blocks of ancient sialic crust composed of the 2.7 Ga old Archaean granulite complex (Rosen, 1986, Int'l Geol. Rev., 57, no. 3, 367-376). A sequence from gneisses to migmatites and further to granites in association with tectonites has been established here. Geochemically, the sequence shows an influx of SiO_2, K_2O and incompatible elements but depletion in Fe-group elements. At the main stage the process appears to have been in good accordance with the model of partial melting.

Fluid inclusions in quartz have been studied in the mineral association Bi-Pl-Kfsp-Q in granites and in zonal pegmatite veins containing Ab and Musc as well. Recrystallised melt inclusions, 2-5 mkm [μm?] in size, in granite contain fine-grained quartz, feldspars, biotite and gaseous bubbles comprising about 1/10 of the inclusion volume. The solid phase started to melt at 700-720°C. More intense melting took place at 760-820°C, and Th of the inclusions was reached at 860-900°C.

In pegmatites three types of inclusions have been established: (1) polycrystalline inclusions; (2) inclusions containing several gaseous, liquid and solid phases, with carbon dioxide also present; and (3) inclusions containing two phases—gas and liquid. Inclusions of type 1, which occur in the outer parts of pegmatite bodies, show Te of ~650-660°C, and of total melting up to 750°C. Melt coexists with gaseous bubbles at higher T, and Th takes place at 790-840°C. Polyphase inclusions of type 2, which contain crystals of salt, have Th(L) at 650-350°C. The two-phase inclusions of type 3 have Th from 400 to 150°C.

As a whole, partial melting of previous rocks is the main process of granite magma generation. This process began as tectonic deformation, resulting in an increase in permeability and K-Si-H_2O-fluid invasion. At increasing T it continued with partial melting, migmatite generation, and in situ separation of granite magma. It finally came to an end during cooling when, first, hot fluid in equilibrium with melt caused pegmatite vein formation (as is established from the outer parts of veins) and, second, hydrothermal fluid of low T (as is established from the inner parts of pegmatite veins) marked the last stage of the process. These data refer to the primitive and early pre-batholithic type of granite formation, which seems to be widespread in environments of continental collision. (Authors' abstract)

ROSEN, O.M. and **SONYUSHKIN, V.E.**, 1989b, Fluid inclusions in polymetamorphic rocks of Anabar shield: Differences in fluid regime of metamorphism and partial melting (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-718-719. Authors at Academy of Sciences of the USSR, Moscow, U.S.S.R.

The Anabar shield is the northern window of crystalline basement of the Siberian platform. The Archean Anabar granulite complex of 2.7 Ga age is of the most widespread, the Proterozoic Lamujka complex of 1.9 Ga age occupies about 1/5 of the shield. [They are] formed by transformation along fault belts of granulites under amphibolite conditions and composed of blasto-tectonites, hornblende-migmatite gneisses (originated by the retrograde metamorphism of granulites), migmatites and granites. The methods of thermometry, cryometry, electron microscope and microprobe analyses were used to study fluid inclusions in quartz of migmatite in enderbite of plagioclase-quartz-hypersthene-magnetite composition in the Anabar complex and in quartz of the Lamujka migmatite composed of K feldspar-plagioclase-quartz-biotite-hornblende-ilmenite association.

In the Anabar enderbitic migmatites (Fig. 1a), the inclusions are composed of high-density CO_2 and seem to be of P and PS origin. The Lamujka migmatites (Fig. 1b) contain mostly H_2O inclusions as well as mixed CO_2 + H_2O inclusions and CO_2 inclusions. NaCl, KCl and $CaCl_2$ were found in the saline residues of H_2O inclusions by electron microscope and microprobe analyses. In these migmatites melt inclusions are described to be 10-15 mkm size [sic]. The fine-grained devitrified glass-like material and grains of 1-2 mkm size composed of quartz, K feldspar, plagioclase and biotite were established by microprobe analysis.

Taking into account the Th of melt inclusions and the density of CO_2 inclusions, the conditions of rock-forming processes were estimated as follows: the granulitic facies P = 8.5-10 kbar, T = 850-900°C, the amphibolitic facies P = 6.0-6.5 kbar, T = 780-820°C. Quartz of the later tectonites was formed during post-granitic H_2O fluids at P = 0.7 kbar, T = 270°C.

The data show that a partial melt of granitic composition was generated under granulite facies conditions in the presence of a CO_2 fluid and under amphibolite facies conditions during mostly H_2O fluid invasion. These two melting processes were separate by ~1.0 Ga time interval. The important difference is the change of CO_2 fluid composition in the Archean to a H_2O fluid in the Proterozoic. (Authors' abstract)

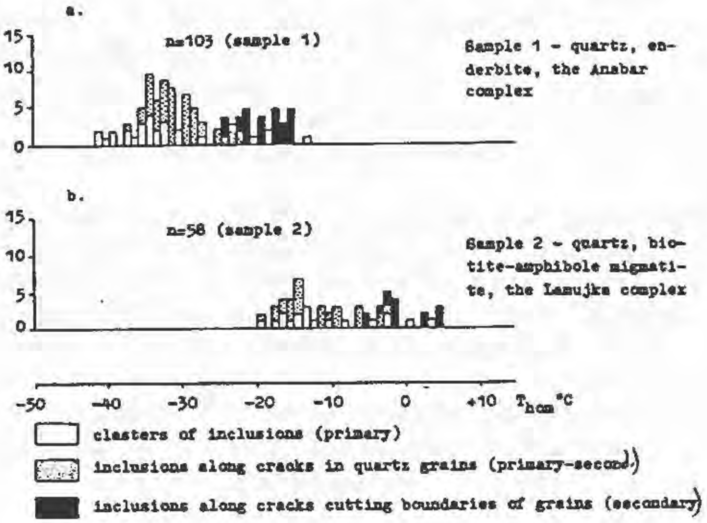


Figure 1—Temperature of homogenization in CO_2 inclusions of different morphology in quartz.

ROSENBAUM, J.M., ZINDLER, A. and RUBENSTONE, J.L., 1989, Absolute concentrations of incompatible elements in mantle fluids (abst.): Eos, v. 70, p. 510. Authors at Lamont-Doherty Geol. Observatory of Columbia Univ., Palisades, NY 10964.

We have measured trace element concentrations (by isotope dilution mass spectrometry) in aliquots of clean minerals hand-picked from mantle peridotite nodules. Each mineral separate contains a different amount of trapped mantle fluid. Mass balance on the bulk system of FI plus host matrix constrains the *absolute* concentration of several trace elements (K, Rb, Cs, Ba, U, and Pb) in the mantle fluids. The mass balance equation for the fluid-matrix system can be arranged in the form

$$C_f = 1/X_f(C_t - C_s) + C_s$$

where C is concentration; X is mass or volume fraction; and the subscripts t, f, and s stand for the bulk system, fluid, and matrix components, respectively. Our data give the slope, $(C_t - C_s)$, and intercept (C_s), for a straight line on a plot of C_f versus $1/X_f$. Fluid volumes estimated using both visual observations and an inclusion distribution model then bracket the concentration of the various elements in the fluid component. Data of pyroxenes from Nunivak Island, Alaska, suggest the following fluid concentration levels: (5785 < K(ppm) < 8308), (1616 < Rb(ppb) < 4185), (150 < Ba(ppm) < 201), and (88 < Cs(ppb) < 435). These concentrations yield K/Rb (~2000) and K/Ba (~40) ratios similar to that of mantle amphiboles. Initial data from San Carlos pyroxenes, however, show fluid K/Rb (~300) closer to that found in alkali basalts.

This fluid may be important in explaining the observation that even the most fertile mantle peridotites contain far lower silicate-hosted abundances of the highly incompatible trace elements than required to produce a basalt on partial melting. If this type of fluid is present in, or is introduced into, a source region in quantities greater than those observed in our samples, it may serve to elevate the existing trace element levels to those necessary to produce a basalt. Using the fluid concentrations from the Nunivak sample as an example, ~1-2% fluid by volume would be necessary to enrich a typical trace element depleted lherzolite matrix sufficiently to generate a tholeiitic basalt on melting. (Authors' abstract)

ROSENBAUM, J.M., ZINDLER, A., RUBENSTONE, J. and JAFOUTZ, E., 1989, Fluid inclusions in mantle xenoliths (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 56. First author at Lamont Doherty Geol. Observatory and Dept. Geol. Sci., Columbia Univ., Palisades, NY 19064.

We are currently studying mineral separates from mantle-derived spinel lherzolites to determine the effects of the presence of FI (<1 μm to 40 μm size) on the highly incompatible trace element budgets (Sm, Nd, Sr, Ba, K, Rb, Cs, U, Th, Pb) and isotopic composition (Nd, Sr, Pb) of the bulk silicates. These nodules are the only portion of the mantle sample isotopically similar (Nd, Sr, Pb) to Mid-Ocean Ridge Basalts (MORBs). While their major element composition is fertile relative to basalt genesis, their trace element content is far below that which would be predicted for a MORB source region.

We have carefully divided pure mineral separates into FI-free and FI-rich aliquots by hand-picking. After gently grinding the inclusion-free picks, all aliquots were leached to eliminate surface contamination and analyzed by mass spectrometry. A comparison of inclusion-rich and inclusion-free pyroxene separates displays similar enrichment patterns from widely varying locales. Sr, Nd, and Sm concentrations show little variation. U, Pb, Ba, K, Cs, and Rb concentrations, however, are all enriched in the inclusion-bearing aliquots. The level of enrichment correlates positively with our visual estimates of the percentage of inclusions in each pick. Data from clinopyroxene separates from a nodule from San Carlos, AZ, imply that the fluids have a low $^{238}U/^{204}Pb(\mu)$ relative to the silicate matrix although the exact value cannot be determined at this time. Our data show that the bulk silicate U, Pb, Rb, Cs, and Ba budgets may be controlled by the fluid phase. We are currently working on placing limits on the absolute concentrations of the highly incompatible trace elements in the fluid phase.

The Pb, Nd, and Sr isotopic compositions of the lherzolites all overlap the MROB [MORB?] field. While the Pb isotopes cluster near the geochron and are consistent with a single-stage evolution model with $7.9 \leq \mu \leq 8.3$ and $k \approx 3.9$, the high $^{143}Nd/^{144}Nd$ and low $^{87}Sr/^{86}Sr$ observed are usually attributed to a melt-induced fractionation event. The perturbed Nd and Sr isotopic composition and undisturbed μ and k imply that one must look towards a non-melt controlled process in order to account for the variations of μ implied by Pb isotopic studies of modern basalts and the variations of k inferred from Th isotopic studies of MORBs.

When a modally-reconstructed, silicate, whole rock budget for the elements of our study is compared with a calculated range of source concentrations for a batch melting model using a 5-15% melt fraction, conservative bulk distribution coefficients (the lowest values from the literature), and average MORB concentration data (Joides summary, in press), the deficit in trace element concentrations of the lherzolites is easily seen. Applying the largest enrichment factors we have observed to the lherzolite concentration data narrows the gap between the observed and modelled source concentrations, but does not close it completely. The fluid-hosted enrichments that we measure display the trend one would need to turn the trace element depleted lherzolite into a potential MORB source but the absolute level of enrichment observed for most trace elements is still below that which would be necessary to produce a basalt from the lherzolite. (Authors' abstract)

See also Zindler et al., this volume. (E.R.)

ROSI, M. and **SIGURDSSON, H.**, 1989, Evolution of volatiles in the magmatic system of the Campi Flegrei caldera, Italy (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 227. First author at Inst. Mineral. e Petrog., Univ. Pisa, Pisa 56100, Italy.

The active Campi Flegrei volcanic complex belongs to the alkali-potassic province of western Italy. The complex is dominated by a 12 km diameter caldera formed during the eruption of the Campanian ignimbrite 35,000 y.b.p. After the main collapse, the caldera was progressively filled by products of successive eruptions which have continued to historical time. Post-35,000 yr activity has occurred as several vents scattered inside the caldera, showing a steady decline in eruptive intensity with time. Significant periods of activity were 5,000 and 3,700 y.b.p. and the Monte Nuovo event of 1538 AD. Four explosive eruptions which have produced widely dispersed tephra fallout in the last 5,000 years have been studied in detail in terms of eruption dynamics and petrology. These are the eruptions of Agnano (4,300 y.b.p.), Astroni and Averno (both 3,700 y.b.p.), and Monte Nuovo 1538 AD.

Electron microprobe analyses of the composition of glass inclusions trapped in phenocrysts from the tephra provide information on pre-eruption volatile content and evolution of the magmas. Host mineral crystallization has little affected the inclusion composition. Results show that liquid compositions of magmas erupted in the successive eruptions are remarkably similar, and that the observed whole-rock compositional trends with time are dominantly related to modal crystal content. Results indicate a progressive compositional evolution of the Campi Flegrei magmatic system tapped in these eruptions. Thus a systematic increase in Na_2O and decrease in MgO is observed in trapped glass inclusions with time. Total volatile content, as determined from inclusion analysis, shows a range from 3 to 4.5 wt %, with a general correlation between inferred H_2O content and the observed eruption intensity. The magmas are exceptionally Cl-rich, judging from glass inclusion analyses (7,000 to 10,000 ppm Cl), whereas S content is modest (200 to 350 ppm S) but in accord with the low iron content of these magmas. (From authors' abstract by E.R.)

ROSS, K.V., 1989, A fluid inclusion study of the Shear Lake deposit, Northwest Territories: BSc thesis, Univ. Waterloo, Waterloo, Ontario.

The Shear Lake deposit is in Proterozoic orthoquartzites of the Hurwitz Group. A major conformity separates the Proterozoic sediments. The orthoquartzite strikes approximately east-west and dips 10-15 degrees to the south. The principal structures are subvertical, anastomosing, east-west striking shears. Pyrite and Au has been precipitated in these shears. The underlying Archean rocks host Au deposits (Cullaton Lake B Zone Mine) in Fe formations in greywacke sequences.

A FI study was conducted to characterize the fluids associated with ore emplacement in the Shear Lake deposit. The vein quartz was precipitated synchronously with ductile deformation, resulting in quartz that is highly strained and recrystallized. No P inclusions survived the deformation, therefore this study is based on S inclusions which limits the interpretation of the data.

Evidence of three types of fluids was found: a) a dense (0.85-0.95 gm/cc) CO_2 fluid (100% CO_2), b) an H_2O-CO_2 fluid (30-70% CO_2) of low salinity (5.5-8.0 wt % NaCl eq.) and c) a low salinity aqueous fluid (4.0 wt % NaCl eq.). The H_2O-CO_2 inclusions decrepitated between 210-250°C. Th of aqueous inclusions was at 157° and 270°C. (Author's abstract)

ROTHFUCHS, T., WIECZOREK, K., McNULTY, E.G., GUPTA, S.K. and **CLARK, D.**, 1989, The brine migration test—A nuclear waste repository simulation experiment at the Asse Salt Mine—Federal Republic of Germany: Mat. Res. Soc. Symp. Proc., v. 127, p. 613-620 (Sci. Basis for Nuclear Waste Management XII). First author at Gesellschaft für Strahlen- und Umweltforschung mbH München, Institut für Tieflagerung, D-3300 Braunschweig, F.R.G.

Discusses the movement of water from various sources when the host salt is subjected to a thermal gradient. (E.R.)

ROVETTA, M.R., BLACIC, J.D., HERVIG, R.L. and HOLLOWAY, J.R., 1989, An experimental study of hydroxyl in quartz using infrared spectroscopy and ion microprobe techniques: J. Geophys. Res., v. 94, no. B5, p. 5840-5850. First author at Dept. Chem., Arizona State Univ., Tempe, AZ.

We have measured the concentrations of hydroxyl, deuterium, Al, Fe, Li, Na, K, and Rb in a natural quartz crystal before and after hydrothermal treatment of 1.5 GPa and 800°-1050°C. We employed microbeam infrared spectroscopy and ion probe techniques to avoid impurities trapped in healed cracks and FI that might bias a normal bulk analysis. The fH_2 of our experiments were buffered to the hematite-magnetite-(OH) fluid, nickel-nickel oxide-(OH) fluid, or iron-wustite-(OH) fluid phase assemblages. After hydrothermal treatment, the samples contained local concentrations of H or D of several hundred atoms/10^6 Si (the starting crystal contained 45 H/10^6 Si). We did several experiments with Al_2O_3 or RbCl added to the sample charge and found local Al enrichment where the D concentration was high but no Rb enrichment. Finally, we measured trace elements and hydroxyl in a quartz sample after plastic deformation in a talc furnace assembly; in regions of the sample containing basal and prismatic deformation lamellae (but no visible healed microcracks at 400x optical magnification) hydroxyl had increased to ~200 OH/10^6 Si with no increase in Al or Fe. Samples enriched in hydroxyl but no Al (including the plastically strained sample) gave infrared spectra resembling natural amethyst crystals. We observed that the sharp pleochroic peaks near ~3400 cm^{-1} and present in the starting crystal, were very intense only in samples showing Al enrichment, whereas the intensity of the sharp pleochroic peaks near 3600 cm^{-1} and broad isotropic absorption were independent of Al. Our analyses indicate that more H was introduced into the treated samples than Al or Fe. Because one proton or alkali cation is needed to screen each Al or Fe atom substituted into a Si lattice site, we conclude that the hydrothermal treatment had produced new hydroxyl defects in the quartz that did not contain Al or Fe. Although the speciation of this excess hydroxyl is unknown, it is present in all varieties of quartz that show hydrolytic weakening: synthetic quartz, amethyst, hydrothermally treated natural quartz crystals, and natural quartz deformed in talc assemblies. In the absence of microcracking or solution-precipitation mechanisms that may mechanically trap OH or H_2O molecules, we suggest that H diffusion, and reaction with lattice O, may introduce hydroxyl defects into quartz and contribute to hydrolytic weakening. (Authors' abstract)

ROWAN, E.L. and LEACH, D.L., 1989a, Implications from fluid inclusions for the hydrology and sulfide precipitation mechanisms of the Viburnum Trend lead-zinc district, southeast Missouri: U.S. Geol. Survey Open-File Report 1978, p. 35-36.

ROWAN, E.L. and LEACH, D.L., 1989b, Constraints from fluid inclusions on sulfide precipitation mechanisms and ore fluid migration in the Viburnum Trend lead district, Missouri: Econ. Geol., v. 84, p. 1948-1965. Authors at U.S. Geological Survey, P.O. Box 25046, Denver, CO 80225.

Measurements on fluid inclusions in hydrothermal dolomite cements place constraints on sulfide precipitation mechanisms and on the thermal-hydrologic processes which formed the Viburnum Trend Mississippi Valley-type Pb district. Th and freezing point depressions were determined for fluid inclusions in Bonneterre Dolomite-hosted dolomite cements in mine samples, as well as drill core from up to 13 km outside the district. A well-defined cathodoluminescent zonation distinguishes dolomite growth zones in the Viburnum Trend as older or younger than main-stage mineralization (octahedral galena) and facilitates correlation with other dolomites outside the Viburnum Trend.

Th and salinities in samples from mines are not systematically different from those of samples outside the district. Medians of Th distributions differ by not more than 25°C, so that a T gradient, if present, should not have exceeded ~25°C within the study area. These observations are interpreted to indicate that the Viburnum Trend was not strongly thermally anomalous with respect to surrounding country rock and that fluid flow occurred on a broad scale through not only the Lamotte Sandstone but through the overlying Cambrian carbonates as well.

The absence of a significant, recognizable decrease in T either vertically within the section or E-W across the district, coupled with the minor amount of silica in the district, argues against cooling as a primary cause of sulfide precipitation. Fluids whose primary aquifer was the Lamotte Sandstone, predominantly a quartz arenite, should have been in equilibrium with quartz. Quartz in the Viburnum Trend occurs as a minor, drusy, vug-lining phase, but the district lacks the intense silicification found in other Mississippi Valley-type districts such as Tri-State (Oklahoma, Kansas, Missouri). Quartz solubility is strongly T-dependent and, under equilibrium conditions, a decrease of 10°C or more should have precipitated at least as many moles of silica as galena (assuming a galena solubility of between 1 and 10 ppm). Clearly this is not the case, as galena is far more abundant than quartz in the Viburnum Trend.

Ice final-melting T (T_m) in fluid inclusions generally range from -14° to -27°C for P dolomite-hosted inclusions. Using these T_m values and cation ratios for the inclusion fluids, absolute concentrations for the individual cations and chloride were calculated using the thermochemical model of Spencer et al. (1990). The corresponding high but variable salinities, 3.9 to 5.9 chloride molality, are evidence for the presence of more than one distinct fluid during mineralization.

In a reduced S mineralization model with Pb carried as chloride complexes, dilution is also a possible sulfide precipitation mechanism. The difference in Pb solubility (for an equal quantity of reduced S) in the extremes of the chloride concentration range, 3.9 vs. 5.9 molal, reaches 1 ppm only for pH values below ~4.5 Accepting 1 ppm as a minimum metal concentration for a viable ore-forming fluid, dilution only appears capable of precipitating sulfides in a fluid with pH near the lower limit of values considered geologically reasonable or attainable.

Dolomite cements hosting warm (~105°-125°C) saline fluid inclusions are ubiquitous in the porous dolomitic facies of the Bonneterre Dolomite. Based on stratigraphic reconstructions, however, it is unlikely that the Bonneterre was buried deeper than 1.5 km. The distribution of warm inclusions beyond the Viburnum Trend district implies that fluid migration was regional in scale. Fluid inclusion T inconsistent with typical basement heat-flow-controlled geothermal gradients (25°-35°C/km) may be explained by long-distance migration of warm, basin-derived brines. Elevated T observed in fluid inclusions at shallow stratigraphic depths are consistent with a gravity flow hydrologic system characterized by rapid flow rates and the capacity for advective heat transport. (Authors' abstract)

ROYZENMAN, F.M., IONKINA, Ye.A., KHUDADYAN, K.V. and VALYASHKO, L.M., 1988, Carbon dioxide wave in cooling hydrothermal solutions: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 11-12 (in Russian). First author at Moscow Geol.-Prospecting Inst., U.S.S.R.

Ore bodies were studied that belong to the types of feldspar, muscovite and rare-metal pegmatites, phlogopite-bearing magnesia skarns, Cu-Ni sulfide ores, etc. Ore bodies containing disseminated ores formed during one stage at the interval of Td 480-300°C [sic, A.K.]. CO_2 concentration in ore-forming solutions is low (1-3 mole/kg H_2O). At 80-95% of ore bodies the ore mineralization finished at this stage, yielding poor spotted ores, although the bodies sometimes have large dimensions. Ore bodies with concentrated rich ores formed in two essential stages of mineralization: Td 480-300°C and 300-140°C. The CO_2 concentration changed, achieving a maximum at 300-380 and 180-200°C (up to 16 moles/kg H_2O). The peak concentration of CO_2 was found also at 300-400°C in the experimental system H_2O-CO_2-NaCl (Takenouchi and Kennedy, 1968); such an analogy suggests a relatively closed ore-forming system. In bodies bearing disseminated ores, the gas phase escapes outside the ore-forming system ("geological trap"). The CO_2 concentration changes influence the pH value of the solution. The CO_2 content variation essentially influences the ore precipitation from a post-magmatic solution; its increase causes a higher solubility of CaO, MgO, Fe_2O_3, NiO, SnO, U_2O_5 [sic, A.K.], and Na_2O, but a lower solubility of Al_2O_3 and SiO_2. (A.K.)

RUBIN, K.H. and MACDOUGALL, J.D., 1989, Submarine magma degassing and explosive magmatism at Macdonald (Tamarii) seamount: Nature, v. 341, 50-52. Authors at Geological Research Division, A-020, Scripps Institution of Oceanography, La Jolla, CA 92093.

Macdonald seamount is an active volcanic centre located at 29°28'S, 140°25'W in the south-central Pacific. Since its discovery in 1968, a number of expeditions have surveyed and dredged rocks from the seamount. during a Scripps Institution of Oceanography expedition in October 1987, the first direct observation of volcanic activity at Macdonald was made when a small eruption occurred spewing forth scoriaceous basaltic rocks which briefly floated to the sea surface. The rocks were accompanied by huge bubbles of volcanic gas that created large sea surface slicks (H. Craig, pers. comm.). Similar activity at Macdonald was observed by a joint French-German team in January 1989 using the submersible *Cyana*. Here we look at the radio-geochemical features of the lone rock recovered from the October 1987 eruption. We present analyses of U-series nuclides from the first observed eruption of Macdonald (also known as Tamarii) seamount with interpretations focusing on the timescales of magmatic events and the implications of uranium-series data for magma degassing. This highly gas-charged magma lost all of its volatile ^{210}Po upon eruption. Based on this, estimates of the fluxes of other volatile elements to seawater, which may contribute significantly to their oceanic budget, are calculated. High ($^{230}Th/^{232}Th$) and $^{87}Sr/^{86}Sr$ ratios, common signatures of altered crust, suggest that the explosive nature of the Macdonald volcanism results partly from the sealing of magma conduits by seawater circulation. (Authors' abstract)

RUMBLE, D., III, CHAMBERLAIN, C.P., ZEITLER, P.K. and **BARREIRO, B.**, 1989, Hydrothermal graphite veins and Acadian granulite facies metamorphism, New Hampshire, USA, *in* D. Bridgwater, ed., Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, pp. 117-119. First author at Geophysical Lab., 2801 Upton St. NW, Washington, DC 20008.

Pertinent to the carbon species in FI. (E.R.)

RUSS-NABELEK, Carol, 1989, Isochemical contact metamorphism of mafic schist, Laramie Anorthosite Complex, Wyoming: Amphibole compositions and reactions: Am. Mineral., v. 74, p. 530-548. Author at Dept. Geol., Univ. Missouri, Columbia, Columbia, MO 65203, USA.

It is shown that progressive metamorphism as exemplified by the various hornfels of this study, is indicated by progressive loss of water with increasing T without loss of Cl or F. (From author's abstract by E.R.)

RYABCHIKOV, I.D. and **ORLOVA, G.P.**, 1989, Evolution of mantle fluids and their possible role in ore genesis (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-738.

RYABOV, V.V., 1988, Chemical composition of immiscible liquids in natural glasses from traps: Geologiya i Geofisica, v. 29, no. 11, p. 69-78 (in Russian, translated in Soviet Geol. and Geophys., v. 29, no. 11, p. 62-70).

Intrusive traps of the Siberian craton, among inclusions in native iron (α-Fe) are found in glasses with an emulsion-fluid pattern of glass in glass. The size of the glass segregations reach 2 mm. Spherules of pyrrhotite and α-Fe are noted in the glasses. Peculiarities of the glasses' composition are given in a series of diagrams, where two groups of discrete chemism are clearly distinguished. The average compositions of glasses of the matrix and spheres enclosed in it have (in wt %): SiO_2—71.68 and 41.66, TiO_2—0.62 and 2.94, Al_2O_3—13.69 and 8.24, FeO—3.59 and 17.92, MnO—0.14 and 1.31, MgO—0.86 and 5.80, CaO—3.24 and 13.34, Na_2O—1.52 and 0.79, K_2O—1.83 and 0.51, P_2O_5—0.39 and 6.77, and F—0.02 and 0.26. The wide variations of chemical composition within the groups of siliceous and ferrous glasses, the turbidity of the glasses, the finds of ore spherules in the glass, and the lower iron content in comparison to liquates of the same type from other rocks suggest the possibility of existence of multistage liquation. The basic agents of liquation were P, Ti, and, to some extent, F. (Author's abstract)

RYADNOV, S.N., BAGDASAROV, Kh.S. and **ARZUMANYAN, G.A.**, 1989, Characteristics of vapor-gas inclusions and distribution of the impurities H, C, and N in crystals of leucosapphire: Soviet Physics. Crystallography, v. 34(4), p. 589-591.

RYTUBA, J.J., HERNANDEZ, A.M., RYE, R.O., DEAN, J.A. and **ARRIBAS, A., Sr.**, 1989, Genesis of Almaden type mercury deposits, Almaden, Spain: (abst.): 28th Int'l Geol. Cong. Abstracts, p. 2-741. First author at U.S. Geological Survey, Menlo Park, CA.

All of the ore deposits in the district have undergone regional low to subgreen schist metamorphism which has seriously disturbed the P fluid inclusion record. Stable isotope studies have been carried out on the El Entredicho, Almaden, and Las Cuevas deposits. In the caldera hosted Las Cuevas deposit, $\delta^{34}S$ values of cinnabar throughout the lateral and vertical extent of the orebody range only from 13.3 to 14.4‰ while the values for coexisting pyrites range only from 15.0 to 15.5‰. The narrow range of $\delta^{34}S$ values indicate that the sulfide sulfur was ultimately derived from a large reservoir of seawater sulfate ($\delta^{34}S$ -30‰). H_2S was produced either from the thermochemical reduction of interstitial seawater sulfate (with a nearly constant -15‰ fractionation) and/or from the thermal decomposition of organic matter in the sediment (with $\delta^{34}S$ ~15‰ less than the precursor seawater sulfate). Either scenario is supported by the observation that cinnabar is much less abundant than native mercury at Las Cuevas and it typically occurs at the contact of black shale clasts and tuff. (From authors' abstract by E.R.)

SACCOCIA, P.J. and **SEYFRIED, W.E., Jr.**, 1989, Experimental determination of the dissociation constant for $MgCl^+$ at 300° and 350°C and 500 bars pressure (abst.): Eos, v. 70, p. 1396-1397.

SACHAN, H.K., 1989, Fluid inclusion and isotopic constraints on the origin of ore fluid at the Dubrava antimony deposit (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 10-11. Author at Dept. Mineral. & Petrol., Comenius Univ., 842 15 Bratislava, CSSR.

The Dubrava Sb deposit, one of the most important vein deposits of western Carpathians, is located in granitoid host rocks of Hercynian age on the northern slopes of the Nizke Tatry Mts. (central Slovakia). Detailed mineralogical, geochemical (Chovan 1989), tectonic and lithologic studies (Cillik - Machalek 1983) have been carried out till now, but little is known about genesis and age of mineralization.

The preliminary FI study presented here has been performed on quartz taking place in all mineral parageneses of the deposit. Quartz contain numerous healed fractures with water-rich, two-phase inclusions at room T, displaying typical features of S or PS origin. Inclusion size rarely exceeds 10 µm.

The first mineralization stage on the deposit is characteristic of the high-T assemblage precipitation which includes scheelite and molybdenite. The second mineralization stage is of greatest economic importance and according to textural evidences has been divided into four periods: (1) pyrite-arsenopyrite; (2) sphalerite-zinckenite-stibnite; (3) tetrahedrite-Fe dolomite-barite(?); and (4) barite.

Because of the small size of inclusions, only Th and Tm ice were unequivocally estimated. In very few cases, also Te were obtained using the method of sequential freezing. Salinities calculated from Tm are scattered within the range 5-18 wt % NaCl eq. without significant difference between mineralization periods. Th of inclusions vary between 228-349°C in the 1. stage. In the 2. stage, a systematic decrease of Th from the 1st (345-233°C) to the last period (as low as 105°C) has been revealed. Measured Te are mostly close to the value predicted for $NaCl-KCl-H_2O$ system except for quartz associated with barite which deposition took place in chloride solutions rich in divalent cations (Ca, Mg).

Th versus Tm plots show some distinct trends. Plots for inclusions from quartz associated with scheelite, molybdenite and pyrite-arsenopyrite are quite similar, displaying increase of apparent salinity with decreasing Th. Because no evidence for boiling has been observed by means of inclusion microscopy, it is likely that the trend is a consequence of mixing two fluids - low saline, high T fluid prevailing in the earlier stage of vein formation, and highly saline, low T fluid which prevailed in the later stage of deposition.

Sphalerite-zinckenite-stibnite assemblage does not display changes of Tm with decreasing Th, however, higher Th are in general confined to quartz associated with sphalerite. It is thus suggested that sphalerite and stibnite deposition took place in the same solutions, but at different PT conditions. The similar trend was observed in quartz from tetrahedrite-Fe dolomite paragenesis.

Observed trends and different Te of inclusions indicate the presence of at least two chemically different kinds of solutions that may have been mixed during evolution of the hydrothermal system. The $CaCl_2$-rich solutions typical for barite deposition may be perhaps derived from evaporitic (Permian or Triassic ?) sediments, as suggested for example by Borisenko et al. (1984) for the Rudnany barite-siderite-sulphide deposit (eastern Slovakia), according to composition of inclusion fluids.

The mixing phenomena are also indicated by sulphur isotope systematics observed at the Dubrava deposit. From the 1st stage to the 3rd period of the 2nd stage, sulphide minerals became more enriched in heavy sulphur (from 0.3 to 6.3‰ CDT) indicating dilution of fluids due to crustal contamination. On the other hand, $\delta^{34}S$ in barite vary between 18-30‰ CDT, which is suggestive for the origin from isotopically heavier sulphate derived from sea water or evaporitic sequences (Sachan - Kantor, in preparation). (Author's abstract, references deleted)

SAEZ, R., RUIZ DE ALMODOVAR, G. and **AYORA, C.**, 1989, The Sn-W-quartz vein field of the Bajo Corumbel, Huelva, Spain: The evolution of ore-forming fluids (abst.): ECROFI, European Current Research on

Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 81. First author at Fac. de Geol., La Rabica. Huelva, Spain.

This vein field is the first reported late-Hercynian hydrothermal ore deposit in the South-Portuguese Zone of the Iberian Hercynian belt. The veins cut through the anchimetamorphic sedimentary series and volcanics, and no granite outcrops in the region. Three successive families of veins (A, B and C) and three different episodes of quartz filling (a, b and c) in each type of vein have been distinguished, enabling a representative sampling of the trapped fluids. Most of the cassiterite (I) and scheelite grew near the walls of veins A and B, associated with quartz (Aa, Ba), muscovite, albite, tourmaline and arsenopyrite, which are also represented in the wall rock metasomatism. Scheelite and arsenopyrite also developed with the following quartz (Aa, Bb), whereas a second generation of cassiterite (II) crystals can be found with quartz (Bc) in small cavities.

Two main types of inclusions have been distinguished: *Type I* inclusions are two-phase (L + V) aqueous inclusions with minor amounts of CO_2 and NaCl at 25°C, with L/(L + V) = 0.4 to 0.95; Tm ice = -3 to -0.5°C; Th L = 400 to 210°C; Th V 340 to 330°C (rare); 410 to 340°C (critical behavior). Some of the inclusions form a clathrate, although liquid and vapor CO_2 were never observed. Many of these inclusions decrepitate at T >300°C. *Type II* inclusions which are three-phase (L + V + halite) at 25°C, with L/(L + V) > 0.9; Tm NaCl = 150 to 160°C; Th = 180 to 150°C (liquid homogenization or halite dissolution).

Type I inclusions represent the fluid responsible for most of the mineral transport and deposition. A continuous decrease in T, with stable low salinity, is observed from the first quartz + cassiterite (I) + scheelite growth to the last quartz + cassiterite (II) one. Small variations in CO_2 content and increases in T can be observed throughout the process. A P range between 1 and 1.5 kbars has been roughly estimated. Finally, a completely different hypersaline fluid was trapped as inclusions of type II at the very end of the growth of some quartz crystals in cavities, in the three types of veins. (Authors' abstract)

SAITOH, Genji and KUSAKABE, Minoru, 1989a, Behavior of magmatic volatiles in volcanic eruptions based on glass inclusion analysis: Bull. Volc. Soc. Japan, v. 34, no. 4, p. 275-293 (in Japanese, English abstract). authors at Inst. for Study of the Earth's Interior, Okayama Univ., Misasa, Tottori 682-02, Japan.

The role of volatiles in volcanic eruptions was reviewed in view of the measured concentration of volatiles in glass inclusions in phenocrysts. Since the amount of volatiles in a glass inclusion is very small (typically ranging from 10^{-11} to 10^{-8} mol), special attention has to be paid to the extraction techniques and analytical methods. Advantages and disadvantages were discussed for the four extraction/analytical techniques: (1) vacuum heating method, (2) electron-probe microanalysis, (3) ion-probe microanalysis, and (4) infrared spectrometry.

The glass inclusion analyses suggest that (1) the volatile concentration in a magma of an early stage of eruption is significantly higher than that of the later stage, (2) a gas phase (H_2O, CO_2 and SO_2) accumulates in a magma chamber during its residence at a shallow depth, and (3) accumulation of data on volatiles in magmas contributes to the understanding of the effect of volcanic eruptions on the climatic changes and evolution of atmosphere. (Authors' abstract)

SAITOH, Genji and KUSAKABE, Minoru, 1989b, Analysis of volatiles in glass inclusions in phenocrysts by laser heating-quadrupole mass spectrometry (abst.): Bull. Volcanol. Soc. Japan, v. 34(4), p. 376-377 (in Japanese).

SAMOYLOV, V.S., KOVALENKO, V.I., NAUMOV, V.B., SANDIMIROVA, G.P. and CHIVASHOVA, L.A., 1988, Immiscibility of silicate and salt melts in the formation of the Mushugay-Khuduk alkali complex, South Mongolia: Geokhimiya, no. 10, p. 1447-1460, 1988 (in Russian, translated in Geochem. Int'l, v. 26, no. 5, p. 61-72, 1989). First author at Geochemical Inst., Siberian Division, USSR Academy of Sciences, Irkutsk, U.S.S.R.

See Fluid Inclusion Research, v. 21, p. 472-484. (E.R.)

SANGSTER, D.F., 1989, Thermal comparison of MVT deposits and their host rocks (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A7.

SANGSTER, D.F., NOWLAN, G.S., BARNES, C.R., HITCH, M.W., STRONG, F.F. and **SAUNDERS, C.M.**, 1989, Are Mississippi Valley type (MVT) deposits thermal anomalies? (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-18. First author at Geological Survey of Canada, Ottawa, Canada.

Certain genetic models for MVT deposits are predicated on the assumption that ore fluids were hotter than the surrounding country rock at the time of ore deposition. This assumption has been most commonly based on burial depths and T derived from reconstruction(s) of the stratigraphy at an assumed time of mineralization. Because the latter is seldom known for MVT deposits, burial T derived for country rocks during MVT mineralization are therefore of questionable reliability.

We report here on initial attempts to determine maximum T reached by country rocks surrounding several MVT deposits by compiling Color Alteration Indices (CAI) of conodonts in the host carbonates. In all cases (1) CAI values from carbonate samples within ore zones were indistinguishable from those taken up to 20 km from the ore; (2) within the accuracy of the method, T determined from CAI data correlated well with Th of fluid inclusions in main stage sphalerite in the ores. Thus it would appear that, at least for the districts studied to date, fluids responsible for MVT deposits were at, or near, thermal equilibrium with their host rocks at the time of mineralization.

A detailed study was made in an area of Lower Paleozoic carbonates in western Newfoundland containing several dozen MVT occurrences in addition to one operating mine. Many of these are in carbonates yielding CAI values of 2-3 (90°-200°C), agreeing well with Th in sphalerite. Several others, however, with similar Th, occur in rocks with CAI values as high as 5 (360°-550°C), suggesting *negative* thermal anomalies of at least 300°C. Discrepancies of this sense and magnitude may indicate mineralization, at least in this region, took place only after the host rocks were buried, heated, and then returned to a near surface position. (Authors' abstract)

SANTOS, M.M., DARDENNE, M.A., GUILHAUMOU, N., GIULIANI, G., BENY, C. and **TOURAY, J.C.**, 1989, The metamorphogenic Pontal gold deposit, Goias, Brazil: Fluid evolution from mineralogical and fluid inclusion studies (abst.): Terra abstracts, v. 1, p. 27.

The Pontal mine (Brejinho de Nazaré) is located in the NE part of the Goias state. Presently, 10^4 tons of auriferous quartz (average grade 17.5 ppm gold) have been mined from a lens, 120 m long and 0.5 m thick. This lens is generally concordant with the metamorphic foliation of the surrounding gneisses and locally cut by pegmatitic dikes. Dominant saccharoidal quartz is associated with oligoclase, biotite, hornblende, tremolite-actinolite less than 2% sulfides and disseminated native Au.

P fluid inclusions contain a dense H_2O-CH_4 rich fluid, often associated with solids (e.g., biotite, rutile, siderite, "graphite-like" phase, as determined by Raman microprobe). Tt is >350°C. Different generations of later inclusions contain low salinity aqueous solutions with variable CO_2, CH_4 and N_2 amounts.

Au deposition is supposed to have occurred in a reducing system at elevated T and P compatible with mesozonal conditions. Later hydrothermal fluids led, at lower T, to limited Au remobilization. (Authors' abstract)

SANTOSH, M., 1988, Fluid inclusion studies in characterising metamorphic fluids: A case study on the Kerala granulites: Indian Minerals, v. 42, nos. 3 & 4, p. 187-197. Author at Centre for Earth Science Studies, Trivandrum-695 031.

The data on fluid inclusions in the interbedded charnockite-khondalite-cordierite gneiss sequence of the Precambrian granulite facies terrain of Kerala show a dynamic evolution of fluids from early high density carbonic through mixed carbonic-aqueous to late low salinity aqueous types. The "dry" mineral assemblages need not be a result of fluid-absent metamorphism, but could reflect an equilibrium between the anhydrous paragenesis and CO_2-rich volatile phase. The nature of fluid evolution defines a P-T array, which in turn is interpreted as the uplift path of the metamorphic terrain. The T-convex path crosses CO_2 isochores in the descending order, from higher to lower densities, implying a near-isothermal uplift history. This would suggest a transient geotherm derived by rapid decompression. The process of excavation seems to have proceeded more rapidly than thermal relaxation. (Author's abstract)

SANTOSH, M., JACKSON, D.H., HARRIS, N.B.W. and **MATTEY, D.P.**, 1989, Evidence for entrapment of carbonic fluid inclusions during charnockite formation, south India (abst.): ECROFI, European Current

Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 82. Authors at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes, MK7 6AA, UK.

The abundance of high density CO_2-rich FI found in granulite facies rocks from worldwide localities remains one of the key pieces of evidence for granulite formation through carbonic metamorphism. The proponents of this model, which proposes that CO_2-rich fluids lowered water activities and stabilized granulite facies assemblages, generally assume that high density inclusions were captured during granulite formation. This assumption has come under close scrutiny recently, following evidence that high density inclusions can be captured at low P. In south India, granulites occur as either large areas of massive charnockite or incipient charnockites, which form within amphibolite facies gneisses along oriented zones and as patches (ranging from a few centimeters to a meter across).

We have combined conventional optical FI studies with thermal decrepitation studies to distinguish and characterize discrete FI generations in charnockites and their gneissic precursors. Evidence for entrapment during granulite formation comes from the high density inclusions which characterize the massive and incipient charnockites; these show a marked contrast in entrapment P between two charnockite types, but are compatible with their respective mineral barometric estimates. Quantitative measurements of gas released from these inclusions by stepped thermal decrepitation show that up to four times the volume of CO_2 is entrapped in the incipient charnockites as in the adjacent gneisses (sampled only 10 cm away), thus suggesting a genetic link between charnockite formation and fluid entrapment. Discrete FI generations decrepitate over well-defined T intervals which are similar for different mineral species, indicating that Td are not controlled primarily by mineral structures and may therefore be a direct reflection of entrapment T. (Authors' abstract)

SARDA, Philippe and **GRAHAM, David**, 1989, Mid-ocean ridge popping rocks and degassing at ridge crests (abst.): Eos, v. 70, p. 1401. First author at Laboratoire de Géochemie et Cosmochimie, Institut de Physique du Globe, 75252 Paris, France.

The vesicle size distribution and rare gas abundances in popping rocks from 14°N on the Mid-Atlantic Ridge provide constraints on the behavior of volatiles during ridge crest volcanism. These popping rocks are rare mid-ocean ridge basalts which contain 16-18% vesicles. The logarithm of vesicle population density is linearly correlated with decreasing size in two of the studied samples, suggesting the possibility of (1) continuous and simultaneous nucleation and bubble growth, and (2) the absence of significant perturbations to the size distribution by physical sorting of bubbles during magma ascent and eruption. We tentatively propose that popping rocks may represent cases where minimal gas loss has occurred.

The rare gas concentrations in the popping rocks are the highest measured in glassy ridge basalts ([He] = 50-70 μccSTP/g). The $^4He/^{40}Ar$ ratio in popping rocks is ~2, similar to the production ratio for the depleted mantle, while in most MORB it is >15. This difference is consistent with rare gas solubilities and varying degrees of pre-eruptive vesicle loss for MORB. The rare gas abundance pattern in popping rocks may resemble the pattern for nonvesiculated MORB, and potentially reflects that of the depleted mantle source. This pattern is similar for Ar-Kr-Xe to the "mean MORB" pattern (computed from samples with $^{40}Ar/^{36}Ar > 10,000$). The similarity implies that vesicle loss at ridges does not seriously fractionate the modern flux ratios of the rare gases from their elemental abundance ratios in the depleted mantle. The pre-eruptive degassing flux of He at ridge crests can be crudely estimated from the MORB He deficit compared to popping rocks and the known production rate of oceanic crust. This estimate is a substantial fraction (~1/3) of that derived from the ^3He budget for the abyssal ocean, and suggests that degassing at ridges may be influenced by the dynamics and style of submarine volcanism. (Authors' abstract)

SARKAR, S.N. et al., 1986, Geology and geochemistry of sulphide ore bodies and associated rocks in Mosaboni and Rakha mines sections in the Singhbhum copper belt: Indian School Mines Diamond Jubilee Monograph.

See Jaireth and Sarkar, 1986, Fluid Inclusion Research, v. 20, p. 184, and Changkakoti et al., 1987, Fluid Inclusion Research, v. 20, p. 71. (E.R.)

SARWAR, Golam and **FRIEDMAN, G.M.**, 1989, Former presence of thick post-Devonian strata in northern Appalachian Basin; evidence from fluid-inclusion studies (abst.): AAPG Bull., v. 73(8), p. 1039.

SASADA, Masakatsu, 1987, Fluid inclusions from VC-2A core hole in Valles caldera, New Mexico, U.S.A.: Evidence for a transition from hot water-dominated system to vapor-dominated system: Geothermal Research Society of Japan Meeting, Abstracts (in Japanese, translated by Y. Seki). Author at Geol. Survey of Japan.

The hydrothermal history of VC-2A is recorded in the fluid inclusions in hydrothermal and igneous minerals. Hydrothermal quartz and fluorite were precipitated from a boiling fluid in a hot water-dominated system. At least a 400 m thick pile above the present land surface was presumably eroded if the hydrothermal system was not overpressured. When the water table was at 30 m below the present land surface, the supply of hot water ceased, probably because of hydrothermal mineral precipitation sealing a main conduit. Presently, there is a vapor zone above 240 m depth, although it is not a "true" vapor-dominated system (Goff et al., 1987). However, the hot water has been flowing up to 165-169 m depth after the sealing of the main conduit. The cooling range is about 30-50°C, based on the Th of calcite whose minimum Th fits the present drill hole T. (Author's abstract)

SASADA, Masakatsu, 1988, Microthermometry of fluid inclusions in minerals from geothermal fields [Part I]: Geothermal Energy, v. 13, no. 4, p. 39-55 (295-311) (in Japanese).

A review of many aspects of FI study. (E.R.) See next item.

SASADA, Masakatsu, 1989a, Microthermometry of fluid inclusions in minerals from geothermal fields [Part II]: Geothermal Energy, v. 14, no. 1, p. 27-42 (in Japanese).

See previous item. (E.R.)

SASADA, Masakatsu, 1989b, Fluid inclusion evidence for recent temperature increases at Fenton Hill Hot Dry Rock test site west of the Valles caldera, New Mexico, U.S.A.: J. Volcanol. and Geother. Res., v. 36, p. 257-266. Author at Geol. Survey of Japan, Tsukuba 305, Japan.

The FI in calcite veins and those in quartz of the host Precambrian rocks from the GT-2 drill hole have been studied microthermometrically to determine the recent thermal history of the Fenton Hill Hot Dry Rock test site west of the Valles caldera, New Mexico. The calcite veins were collected from 1876 m and 2624 m depth. They contain P liquid-rich inclusions and S liquid-rich and monophase liquid inclusions. The Th and Tm ice of these inclusions and the S inclusions in quartz from the host Precambrian rocks were measured using a USGS-type gas flow heating/freezing stage. The CO_2 content was also determined semiquantitatively using a microscope crushing stage. Tt was determined on the isochore under the assumption of lithostatic P. NaCl eq. salinity was also determined from Tm after correction for CO_2. Microthermometry of P inclusions in calcite and S inclusions in quartz indicates that the calcite veins precipitated from low-salinity geothermal fluids at T at least 10-15°C lower than the thermal maximum recorded in the S inclusions in quartz of the Precambrian rocks. The lowest T determined from the minimum Tt of S inclusions in calcite is 26°C lower than the present borehole T of 178°C at 2624 m. After cooling the T increased again up to the present geothermal profile. (Author's abstract)

SASADA, M., 1989c, Some problems of application of fluid inclusion microthermometry to geothermal explorations (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-25. Author at Geological Survey of Japan, Tsukuba, Japan. [Paper not presented at Congress. E.R.]

Fluid inclusion microthermometry has been applied to geothermal exploration so far in more than 40 geothermal fields of 11 countries. Fluid inclusions in hydrothermal minerals reflect the thermal history of geothermal fields, but the thermal records of fluid inclusions are not always complete. Th should correspond to the T of formation of geothermal reservoir where the hydrothermal minerals are precipitated, if the P correction for T of trapping is negligible. Actually, Th of fluid inclusions in hydrothermal minerals represent the reservoir T, in most cases at very active geothermal fields where the borehole T are close to a boiling point curve for water (Taguchi, 1982; Hedenquist, 1983). The P-corrected Th may also represent the T of aquifer of the cooling reservoir. Th or P-corrected Th are, however, not accordant to the T of formation, when the geothermal reservoir underwent the following thermal histories after trapping of the fluid inclusions: (1) hydrothermal veins completely filled with minerals on cooling; (2) transition from hot water-dominated system to vapor-dominated system; and (3) recent T increases. The comparison between Th and the final T recovery of boreholes gives more accurate thermal history of geothermal reservoirs. (Author's abstract)

SASADA, Masakatsu and **GOFF, F.E.**, 1989, Fluid inclusions in minerals from the VC-2A core hole of CSDP at the Valles caldera, New Mexico (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 57. First author at Geol. Survey of Japan.

VC-2A is the second core hole of the Continental Scientific Drilling Program, Valles caldera. It penetrates the vapor zone and the top of the liquid-dominated hydrothermal system beneath the acid sulfate alteration zone of Sulphur Springs, which is located on the western edge of the resurgent dome inside the caldera.

The FI in hydrothermal quartz, fluorite, and calcite, and those in quartz phenocrysts in the welded tuff have been studied microthermometrically (Fig. 1). Th of FI in quartz and fluorite from the shallow vapor zone indicate that these minerals were precipitated from boiling fluid in a hot-water-dominated regime early in the history of the system. Relatively high Th data at shallow depths indicate that considerable erosion apparently followed deposition of the hydrothermal minerals, accompanied by a drop in the water table. Minimum Th of S inclusions from several depths above the present water level fit a boiling point curve adjusted to 100°C at 20 m below the present ground surface. T defining this curve are several tens of degrees higher than those of the present thermal profile. However, Th for S inclusions in core samples from below the present water table fit the present thermal profile.

Because a caldera lake was present ~0.5 Ma ago, the water table in the Sulphur Springs area was probably higher than the present one. When the southwestern wall of the caldera collapsed, the caldera lake was drained. This presumably causes a sudden drop in the water table and the hydrothermal system, preventing minerals from trapping liquids above the dropping water table. The vacant interval of Th between the boiling point curve and the present thermal profile above the present water level was produced by the vapor zone cooling processes (Fig. 1). (Authors' abstract)

See also Sasada, 1987b, in Fluid Inclusion Research, v. 20, p. 340. (E.R.)

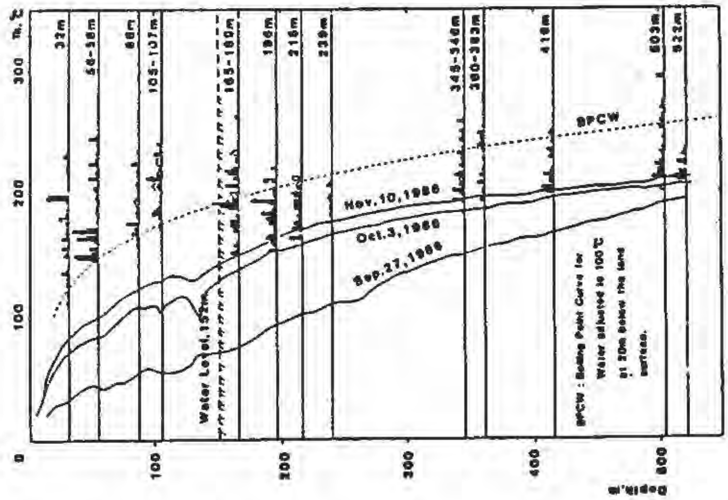


Figure 1. Th-depth diagram of VC-2A. Open symbol: primary inclusion. Solid symbol: secondary inclusion.

SASSANI, D.C., SHOCK, E.L. and **PASTERIS, J.D.**, 1989, Solubility of platinum-group elements in late-stage magmatic/hydrothermal solutions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A262.

SASSANO, G.P. and **SCHRIJVER, K.**, 1989, Framboidal pyrite: Early-diagenetic, late-diagenetic, and hydrothermal occurrences for the Acton Vale quarry, Cambro-Ordovician, Quebec: Am. J. Sci., v. 289, p. 167-179. First author at Dept. Geology, Concordia Univ., 7141 Sherbrooke St. West, Montreal, Quebec H4B 1R6, Canada.

The first part of this paper contains a brief summary of, and commentary on, the various types of framboidal and framboid-like aggregates of pyrite described in the literature. In the second part of the paper, it is argued from our data, as well as from the occurrence of limestone-hosted framboidal pyrite in general, that the early framboidal pyrite is most likely formed during diagenesis. In the third part, the authors ascribe the formation of the columnar aggregates of pyrite and their contained framboids to a genuine hydrothermal event spatially related to the emplacement of a mineralized intrusive and extrusive suite of igneous rocks of the Acton Vale-Upton sector. (From authors' abstract by E.R.)

SATO, H., 1989, Redox states of magmas estimated by Mg-Fe partitioning between plagioclase and magma (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-28-29.

SATO, T., OMORI, Y. and NAMBU, M., 1984, Quantitative analysis of metallic ions associated with fluid inclusions, *in* J. Okano, R. Shimizu and H.W. Werner (eds.), Secondary Ion Mass Spectrometry SIMS IV, A. Benninghoven: Springer-Verlag, Berlin, p. 471-474. First author at Research Institute of Mineral Dressing and Metallurgy, Tohoku Univ., 2-chome Katahira, Sendai 980, Japan.

This is an updated version of a Japanese paper by Nambu et al. (1977), translated in Fluid Inclusion Research, v. 10, p. 326-329. It gives some additional experimental details and 15 analyses of inclusions, for Li, Na, Mg, Al, K, Ca, Mn and Cu, from the Kaneuchi, Ani, Hosokura, Tsuchihata, and Asahi mines. (E.R.)

SAUL, A. and WAGNER, W., 1989, A fundamental equation for water covering the range from the melting line to 1273 K at pressures up to 25,000 MPa: J. Phys. Chem. Ref. Data, v. 18, no. 4, p. 1537-1564.

SAXENA, S.K., 1989, Oxidation state of the mantle: Geochimica Cosmochim. Acta, v. 53, p. 89-95. Author at Dept. Geol., Brooklyn College, Brooklyn, NY 11210.

Phase equilibrium relations are established in a system Mg-Fe-Si-H-O, with and without C, at high P and T. High P-T equations of state for the fluids including non-ideal mixing are used in the calculations. The computed equilibrium data show that an olivine of appropriate mantle composition (10 to 14 mole % fayalite) is stable over a wide range of T and oxygen fugacities in the carbon-free system. If C is introduced, such that the equilibrium assemblage may contain graphite or diamond, the fluid phase in the peridotite + water system consists mostly of H_2O and little CO_2 and CH_4. However, the fluid composition is strongly affected by the Fe content of the system. If Fe is increased (within 10% by moles of the total Fe in the mantle) from undersaturation (i.e., no free Fe present in equilibrium) to that of saturation (i.e, Fe stable as a phase) the CH_4 content of the fluid changes from a low of 1% to a high of 89%. The calculated results show a fluid with as much as 75% methane could be in equilibrium with olivine (13 mole % fayalite) without metallic Fe as a coexisting phase. The fO_2 of the primitive mantle with such a fluid composition would be several log units below that of the quartz-fayalite-magnetite buffer. (Author's abstract)

SAZONOV, V.N., 1989, A correlation between the depth, the metasomatite composition and ore capacity of the berezite-listvenite formation: Doklady Akad. Nauk SSSR, v. 306, no. 1, p. 162-165 (in Russian). Author at Inst. Geol. Geochem. of the Ural Div. of Acad. Sci. USSR, Sverdlovsk, USSR.

Deposits of the gold-quartz and gold-sulfide-quartz types developed mostly in salic blocks of the Earth's crust, in endo- and exocontacts of tonalite-granodiorite massifs. They are accompanied with aureoles of berezitization and listvenitization, and their formation T (Th?-A.K.) ranges from 400 to 150°C. Gold polymetallic deposits were formed in femic and salic blocks, T 410-180°C. (A.K.)

SÄNGER-Von OEPEN, P., FRIEDRICH, G. and VOGT, J.H., 1989a, Ore mineralogy and fluid inclusion studies of the Rodalquilar gold deposit, an acid-sulfate type epithermal gold mineralization in Spain (abst.): Terra abstracts, v. 1, p. 27.

Gold mineralization at Rodalquilar occurs in Late Tertiary calc-alkalic volcanic rocks and is related to a caldera collapse. Mineralized structures show a specific alteration zonation ranging from innermost advanced argillic to more regionally developed propylitic alteration. Overpressured and hypersaline fluids of presumably magmatic origin initiated the hydrothermal system. Subsequent processes were characterized by the inflow of fluids with 3-5 wt % NaCl eq. of probably marine origin and by interactions between both solutions. Au is suggested to have been precipitated from low saline fluids at ~175°C. Au was presumably transported as $Au(HS)_2^-$, and precipitation resulted from boiling solutions accompanied by a decrease in P, T and pH and changes in redox conditions. Integration of all data attribute the Rodalquilar gold deposit to the acid-sulfate type of epithermal Au mineralization. (From authors' abstract by E.R.)

SÄNGER-Von OEPEN, P., FRIEDRICH, G. and VOGT, J.H., 1989b, Fluid evolution, wallrock alteration, and ore mineralization associated with the Rodalquilar epithermal gold-deposit in southeast Spain: Mineral. Deposita, v. 24, p. 235-243. Authors at Inst. für Mineral. und Lagerstättenlehre, Rheinisch-Westfälische Tech. Hoch. Aachen, Wüllnerstr. 2, D-5100 Aachen, Germany.

At Rodalquilar, Au mineralization is found in Late Tertiary volcanic rocks of the Sierra del Cabo de Gata and is related to a caldera collapse. Radial and concentric faults were preferred sites for Au deposition. Hydrothermal activity produced a specific alteration zoning around Au-bearing vein structures, grading from an innermost advanced argillic via an argillic into a more regionally developed propylitic zone. Advanced argillic alteration with silica pyrophyllite, alunite, and kaolinite extends down to several hundred m indicating a hypogene origin. High-grade Au mineralization in vein structures is confined to the near-surface part of the advanced argillic alteration. Fine-grained Au is associated with hematite, jarosite, limonite, or silica. At a depth of ~120 m, the oxidic ore assemblage grades into sulfide mineralization with pyrite and minor chalcopyrite, covellite, bornite, enargite, and tennantite. Two types of fluids from different sources were involved in the hydrothermal system. Overpressured and hypersaline fluids of presumably magmatic origin initiated the hydrothermal system. Subsequent hydrothermal processes were characterized by the influx of low-salinity solutions of probable marine origin and by interactions between both fluids. Deep-reaching, advanced argillic alteration formed from high-salinity fluids with 20-30 eq. wt % NaCl at about 225°C [extensive FI data presented]. Near-surface Au precipitation and silification are related to fluids with T of ~175°C and 3-4 eq. wt % NaCl. Au was transported as $Au(HS)_2^-$, and precipitation resulted from boiling with a concomitant decrease in T, P and pH and an increase in fO_2. All features of the Rodalquilar Au deposit reveal a close relationship to acid-sulfate-type epithermal Au mineralization. (Authors' abstract)

SCHANDL, E.S., O'HANLEY, D.S. and WICKS, F.J., 1989, Rodingites in serpentinized ultramafic rocks of the Abitibi greenstone belt, Ontario: Canadian Mineral., v. 27(4), p. 579-591.

Indexed under FI. (E.R.)

SCHANDL, E.S., WICKS, F.J. and SPOONER, E.T.C., 1989, The stable isotopic composition of the carbonates and their source fluid in the Kidd volcanic complex, Timmins, Ontario (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-121. Authors at Dept. Geol., Univ. Toronto, Ontario M5S 1A1, Canada.

Ultramafic and rhyolitic rocks of the Kidd volcanic complex have been extensively altered to assemblages containing carbonate. Carbonate alteration overprints silicification in the rhyolite and serpentinization in the ultramafic rocks, but predates pervasive sericite/fuchsite and chlorite alterations. Carbonates we selected for stable isotope and FI studies to determine the source of the CO_2-rich metasomatizing fluid. The mean $\delta^{18}O$ and $\delta^{13}C$ compositions of 12 carbonate samples, composed of magnesite, dolomite and ankerite are $+13.8 \pm -0.8(1\sigma)$ and $-0.6 \pm -0.1(1\sigma)$‰, respectively, and are within the general range reported by other investigators from the Timmins area. The $\delta^{18}O$ composition of the fluid which precipitated the carbonates was calculated with the appropriate carbonate-water fractionation curve, and the fluid T derived from P FI. As H_2O-CO_2 phase separation due to boiling was observed, the mean Th of 242 ± -9°C equals the Tt. The oxygen isotopic composition of the fluid -0.2 to +2.3‰, suggests a sea water source with a possible heavier component. Observational evidence suggests that carbonate alteration was synvolcanic, thus coeval with ore deposition. The salinity range of fluid is 1-6 eq. wt % NaCl. Although the $\delta^{13}C$ composition of carbonates supports sea water as the source of CO_2, presence of liquid CO_2 in a number of FI precludes a sea water source. The melting point of CO_2 as low as -57.8°C in some inclusions suggests CH_4 as an additional component in the CO_2-H_2O mixture. We suggest that CH_4 was derived from carbon in carbonaceous sediments deposited during volcanic hiatuses, and CO_2 was derived from a magmatic source. Subsequently, fractionation between the isotopically light magmatic CO_2 (~-3 to -5‰) and the CH_4 could have produced the observed heavier $\delta^{13}C$ values of CO_2 (-0.6 ± -0.1) in the Kidd Creek carbonates. (Authors' abstract)

SCHEEPERS, R., 1989, Geochemical evolution of late Precambrian Cape granites (abst.): Geol. Surv. Finland Special Paper 8, p. 119. Author at Dept. Geology, Univ. Stellenbosch, Stellenbosch 7600, South Africa.

The Cape granite suite consists of a series of high-level plutons with a late Precambrian age, intrusive into a metasedimentary sequence, and covering a time span of ± 100 Ma.

Interpretation of major, trace and REE geochemical data revealed three distinct magmatic associations. Clear distinctions between a calc alkaline, subalkaline, and a "transitional alkaline" suite can be drawn on geochemical and field evidence. The calc-alkaline associations tend to correspond to Australian S-type granites and the subalkaline granites to Australian I-type granites. The term "transitional alkaline" (TA) is used to describe late granites with features corresponding to the Australian A type, but also showing subalkaline characteristics.

The subalkaline granites are typically metaluminous with pyroxene relicts, amphibole, high U and Th values, Ce, Pr and Nd enrichment, as well as major element characteristics corresponding to those of I-type granites. A general feature of these granites is the complex accessory mineral assemblage including tschevkinite, REE fluorocarbonates and thorite as well as a high-T zircon population.

The TA granites are characterized by an agpaitic coefficient between 0.95 and 1, occasionally reaching values above 1. They are enriched in Nb, Ga and other large, highly charged cations as well as in U and particularly Th. A further characteristic of these granites is the high CO_2 content of their fluid inclusions. Their zircons consist of highly complex typological forms, typical of zircon crystallizing at a late stage in an alkaline granite.

A subduction-related environment with two major intrusive phases is envisaged, the first ranging from gabbro to leucogranite with a calc-alkaline affinity, and the second from gabbro to leucogranite with a subalkaline affinity. The TA granites are related to lower crustal remelting at the end of an orogenic cycle. (Author's abstract)

SCHEETZ, B.E., YARBROUGH, W.A. and **PLESKO, E.P.**, 1989, A particulate-sample mounting technique for the laser Raman microprobe: Am. Mineral., v. 74, p. 271-272.

SCHENK, Peter, 1989, Fluid inclusion studies of the Felbertal scheelite deposit (Austria) (abst.): Terra Abstracts, v. 1, p. 35. Author at Inst. Allgemeine and Angewandte Geol., Luisenstrasse 37, D-8000 MHnchen 2.

The Felbertal scheelite deposit offers a good possibility to study the PVTX fluid evolution in minerals and rocks. Detailed studies have been carried out on quartz, beryl, and three different stages of scheelite. From microthermometrical investigations three different types of FI can be distinguished. Aqueous FI of type I are characterized by a variable CO_2 content. They show two or three phases at room T and have been trapped in quartz, scheelite of the second and third stage as well as in beryl. During Alpine metamorphism the CO_2-bearing fluids get enriched in CH_4 in the course of time. Aqueous FI of type II show two phases and range in salinity between 4 and 11 wt % NaCl eq. They are of S origin in all minerals except in some scheelites of stage three which may contain very seldom type II inclusions probably of P origin. Latest aqueous FI of type III display one or two phases at room T. They are characterized by salinities lower than 4 wt % NaCl eq. and are hosted only by quartz along badly healed ruptures. The bulk Th data for FI in quartz range from ~+360° to +100°C and in scheelite from +360° to +200°C. From FI data it is evident that all fluids are of Alpine origin. Obviously no premetamorphic fluids are preserved. (Author's abstract)

SCHIFFMAN, P., ZIERENBERG, R.A. and **McCLAIN, J.S.**, 1989, Hydrothermal crusts from the Sea Cliff hydrothermal field, Gorda Ridge: A modern analogue of silicified zones found within ophiolitic massive sulfide deposits? (abst.): Eos, v. 70, p. 1397.

SCHIFFRIES, C.M., 1989a, Liquid-absent, aqueous fluid inclusions (abst.): Eos, v. 70, p. 495. Author at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008.

Raman spectra and microthermometric data are reported for a class of aqueous FI that is distinguished by the absence of a liquid phase at 20°C. The inclusions consist of several solid phases and a low density vapor at room T. Initial melting occurs at ~+28°C, and the inclusions ultimately homogenize to an aqueous liquid at elevated T. At 20°C most of the water occurs as structurally bound H_2O in hydrate minerals, and the vapor phase contains a relatively small amount of water. Micro-Raman spectra of individual inclusions indicate the presence of two hydrates at room T. One hydrate has Raman bands at 1660 and 3430 cm^{-1} that are indicative of antarcticite ($CaCl_2 \bullet 6H_2O$). The second hydrate has not been positively identified, but the most likely possibility is a polymorph of $CaCl_2 \bullet 4H_2O$. Final hydrate melting occurs at 32 to 38°C. Halite is present in some inclusions (Tm (halite) = 144 to 185°C), and it may be metastably suppressed in other inclusions.

The microthermometric data can be interpreted in terms of the liquidus phase diagram for the system $CaCl_2$-$NaCl$-H_2O. If the subsolidus assemblage consists of antarcticite, $CaCl_2 \bullet 4H_2O$ and halite, then initial melting occurs at a ternary reaction point (~+28°C), rather than the eutectic point (Te = -52°C) as generally assumed. FI with the postulated subsolidus assemblage have a maximum water content of 48 wt %, neglecting the mass of the vapor.

The inclusions reported in this paper occur in quartz from a mafic pegmatoid in the Bushveld Complex. Similar inclusions probably occur in other geological environments, but they may be overlooked or misinterpreted because their solidus T is above 20°C. (Author's abstract)

SCHIFFRIES, C.M., 1989b, Fluid inclusion phase equilibria in the system $CaCl_2$-$NaCl$-H_2O: Constraints on bulk composition (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia] (abstract received too late to be printed in program, but paper presented orally). Author at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008.

FI in quartz from a mafic pegmatoid in the Bushveld Complex consist of antarcticite ($CaCl_2 \bullet 6H_2O$), halite, liquid, and vapor at 20°C. The identification of antarcticite has been confirmed by micro-Raman spectroscopy. At 20°C the spectrum is characterized by asymmetrical peaks at 1660 and 3430 cm^{-1}, which correspond respectively to the bending and stretching modes of water in the mineral structure. A simple technique has been developed for measuring Raman spectra of FI at cryogenic T. At -173°C the antarcticite spectrum exhibits splitting of fundamental vibrational modes into closely-spaced multiplets. Within the limits of analytical uncertainty, the measured peak positions are identical to the values reported for synthetic antarcticite at the same T.

Microthermometric measurements of phase transitions in the FI can be interpreted in terms of the vapor-saturated liquidus phase diagram for the system $CaCl_2$-$NaCl$-H_2O. In theory, the bulk composition can be determined from two measurements: (1) Tm (antarcticite) in the presence of a cotectic liquid plus halite and vapor, and; (2) Tm (halite) in the presence of liquid and vapor. Neglecting the mass of the vapor, Figure 1 shows that the bulk composition lies at the intersection of the Tm (halite) isotherm, and the mixing line between halite and the point on the halite-antarcticite cotectic that corresponds to Tm (antarcticite). In practice, the bulk composition cannot be precisely determined by this technique because there are large uncertainties in the experimental isotherms and equation of state for the relevant portion of the phase diagram.

Constraints on the bulk composition of $CaCl_2$-$NaCl$-H_2O FI can be deduced from qualitative observations of the sequence of equilibrium phase transitions that occur with increasing T. The liquidus phase diagram can be divided into regions that are each characterized by a unique sequence of phase transitions, and the bulk composition of a FI can be assigned to the region that corresponds to the observed sequence of phase transitions. Given the topology of the phase diagram, relatively small variations in the bulk composition of highly saline FI may produce large differences in the sequence of phase transitions. (Author's abstract)

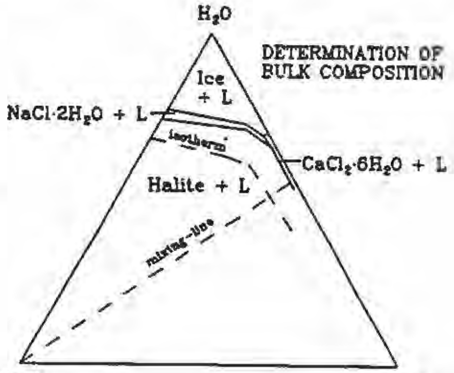


Figure 1. Vapor-saturated liquidus phase diagram for the system $CaCl_2$-$NaCl$-H_2O (mass units). The bulk composition of the inclusion lies at the intersection of the isotherm and the mixing-line.

SCHIFFRIES, C.M., 1989c, Liquid-absent aqueous fluid inclusions: Ann. Rept. Dir. Geophys. Lab., Carnegie Inst. Wash. 1988-1989, p. 30-32.

See two previous items. (E.R.)

SCHIFFRIES, C.M., 1989d, Liquid-absent fluid inclusions and phase equilibria in the system $CaCl_2$-$NaCl$-H_2O: Geochim. Cosmochim. Acta, v. 53, p. 611-619.

Full paper for previous item. (E.R.).

SCHIØTTE, Lasse, 1989, On the possible role of fluid transport in the distribution of U and Pb in an Archaean gneiss complex, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 299-318.

SCHLEUSENER, J.L., BARNES, H.L., DRUMMOND and **PALMER, D.A.**, 1989, Stability of acetate in hydrothermal solutions (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-48.

SCHMIDT-MUMM, A., 1989, Evolution of fluid systems during the Upper Proterozoic Damara-orogenesis at the southern margin of the Damara-orogen/Namibia: Göttinger Arb. Geol. Paläont., v. 41, 93 pp. (in German, English abstract). Author at Institut für Geologie und Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400 Göttingen, B.R.D.

A mobile decrepitometer was developed for FI studies on mineralisations along the southern margin of the Damara Belt. Fluid systems during orogenesis were related to evaporitic sequences or tectonic brines. At their interface the fluids reacted and released a CO_2-rich phase. (Author's abstract)

SCHOCH, A.E., 1989, Fluid inclusion compositions associated with the Koperberg Suite, Namaqualand, South Africa (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 83. Author at Dept. Geol., Univ. of the Orange Free State, Bloemfontein 9301, South Africa.

(...) The FI in samples from the Koperberg Suite are predominantly too small for microthermometric study. The samples for which results are reported here perforce came from separated localities, so that only a first-approximation synthesis on regional scale can be supplied at present. The FI in the matrix of a megabreccia is nearly identical to the volatile substances entrapped after the peak of the metamorphism in the country rock gneiss, namely nearly pure water (0-2 wt % NaCl eq.) with Th = 375°C and nearly pure CO_2 with Th = 26.5°C. The dominant fluid in the samples of Koperberg Suite studied is a more dense brine (5-14 wt % NaCl eq. with Th = 210 ± 15°C) associated with slightly impure CO_2, with Th-peaks at 8.5°C, 26.5°C and 29.5°C. The magma-associated volatile substances probably had nothing to do with the formation of structures (megabreccias) which were available as conduits. Future work will now concentrate on possible differences between various members of the Koperberg Suite. (Abbreviated from the author's abstract by E.R.)

SCHOTT, Jacques, BRANTLEY, Susan, CRERAR, David, GUY, Christophe, BORCSIK, Maria and **WILLAIME, Christian**, 1989, Dissolution kinetics of strained calcite: Geochimica Cosmochim. Acta, v. 53, p. 373-382. First author at Lab. Géochimie, Univ. Paul Sabatier, 31062 Toulouse Cedex, France.

Interface-limited dissolution of minerals occurs non-uniformly with preferential attack at sites of excess surface energy such as dislocations, edges, point defects, microfractures, etc. Strained crystals are predicted to show higher dissolution rates due to the increased internal energy associated with dislocations and due to enhanced nucleation of dissolution pits at dislocation outcrops on the surface. Using calcite strained to different degrees, we have observed a measurable rate enhancement of two to three times relative to unstrained crystals at T from 3 to 80°C. This rate enhancement is large compared to that predicted from the calculated increase in crystal activity due to strain energy, but small compared to the three orders of magnitude difference in dislocation densities for the crystals tested (10^6-10^9 cm^{-2}). Measurements over a range of pH (4.5-8.3) and T (3-80°C) showed that the rate enhancement increased with increasing pH and decreasing T. Calculations based on the excess free energy of screw dislocations suggest that dissolution rate enhancement should become significant above a critical defect density of roughly 10^7 cm^{-2}, in apparent agreement with our observations.

Crystal dissolution comprises several parallel processes operating in parallel at active sites. The small relative enhancement of dissolution rate with defect density reflects the greater quantity of dissolved material delivered to solution from receding edges and ledges relative to material coming from point defects and dislocations. Our data, coupled with existing information on other minerals, suggest that generally applicable kinetic measurements can be made on low-strain, macroscopic mineral specimens. However, kinetic data on highly strained minerals should include measurement of defect density because of the rate vs. strain correlation. Selective dissolution can be expected to occur in naturally-deformed rocks, where heterogeneity in dislocation distribution could cause solution transfer and deformation. (Authors' abstract)

SCHREIBER, D.W., 1989, Gold mineralization and geologic history of the Pataz region, eastern Cordillera, north Peruvian Andes (abst.): Terra abstracts, v. 1, p. 16.

The most important occurrences of Au are within quartz veins related to the intrusion of the Pataz-Batholith. It is built up by a typical calc-alkaline magma series of I-Type characteristics and was emplaced along an ancient NNW trending fracture zone active during various times of the geologic history. It cuts Precambrian and early Paleozoic metasediments and metavolcanics.

Au quartz veins especially occur near the contact between these basement series and the granitic to monzodioritic plutonics. After a first stage with pyrite and arsenopyrite, Au and electrum were deposited together with some galena, sphalerite and chalcopyrite. Microthermometric measurements of fluid inclusions in quartz show a wide range of Th from >300 to 90°C and chemical variability of medium to highly saline aqueous solutions.

Although most features of the Au quartz veins are consistent with a simple model of Au concentration in late magmatic solutions during differentiation, a country rock origin seems more probable. There is evidence that Au, as the only metal of mining importance in the region, is at least slightly enriched in other geologic environments, too: in the basement, in a skarn deposit, and in veins cutting late Tertiary volcanics. Au could have been leached or mobilized by different magmatic-hydrothermal events from common source rocks in the basement. (From author's abstract by E.R.)

SCHWANDER, Jakob, 1989, The transformation of snow to ice and the occlusion of gases, *in* H. Oeschger and C.C. Langway, Jr. (eds.), The Environmental Record in Glaciers and Ice Sheets: John Wiley & Sons Ltd., pp. 53-67. Author at Physics Institute, Univ. Bern, 3012 Bern, Switzerland.

The gases enclosed in the bubbles of glacier ice represent samples of the atmosphere approximately from the time of bubble formation. The age of this air is different from the surrounding ice. Also, the age cannot be given by a simple value but is described by an age distribution. This age distribution is determined by the mixing in the permeable firn layer and the air trapping rate at the firn-ice transition. At present it is possible to estimate the age distribution, using model calculations, in special cases. More data, especially on the spatial variability of the air permeability and diffusivity in the firn, are needed to permit modeling of more general cases. Tracer experiments would be a further possibility to assess the age of the air in the bubbles of ice. Due to physical and chemical processes, the concentrations of the gases in the bubbles may differ from the atmospheric concentrations. Apparently the gas compositions in bubbles of very cold glaciers (no surface melting during summer) do not differ from samples of the atmosphere. (Author's abstract)

SCHWARTZ, M.O., 1989, Determining phase volumes of mixed CO_2-H_2O inclusions using microthermometric measurements: Mineral. Deposita, v. 24, p. 43-47. Author at Bundesanstalt für Geowissenschaften und Rohstoffe, P.O. Box 51 01 53, D-3000 Hannover 51, FRG.

A new graphical technique has been developed which permits the composition and volumetric properties of mixed CO_2-H_2O inclusions to be determined using microthermometric measurements. If the values of only two of the four variables: (1) density of the CO_2 phase derived from the T and mode of partial homogenization, (2) T and mode of total homogenization, (3) volume fraction of the CO_2 phase at 40°C, and 4) molar fraction of CO_2 of a mixed CO_2-H_2O inclusion are known, the values of the other two variables can be taken from a diagram depicting the relationships between all four variables. The diagram can be used to derive the volume fraction of the CO_2 phase from measurements of the partial and total Th. It can also be employed in the opposite sense for determining the theoretical Th of an inclusion which decrepitates before reaching total homogenization, provided a good visual phase volume estimate is available. The graphical technique can also be applied to mixed CO_2-H_2O inclusions which contain $\leq$6 wt % NaCl. (Author's abstract)

SCHWARTZ, M.O. and ASKURY, A.K., 1989, Geologic, geochemical, and fluid inclusion studies of the tin granites from the Bujang Melaka pluton, Kinta Valley, Malaysia: Econ. Geol., v. 84, p. 751-779. First author at Bundesanstalt für Geowissenschaften und Rohstoffe, P.O. Box 510153, D-3000 Hannover 51, Federal Republic of Germany.

A low-salinity, acid, Sn-bearing, aqueous fluid phase, partly mixed with CO_2, separated from the crystallizing magma. The residual fluids interacted with the solidified part of the granite, cooled, and deposited cassiterite in the range at P of ~440° to 240°C, 1 kbar. The crystallization of cassiterite was followed by arsenopyrite, pyrite, chalcopyrite, sphalerite, galena, Bi sulfosalt, and native Bi. The style of mineralization is a variable, greisen type in the muscovite granite in the center of the pluton and a vein type in the megacrystic medium-grained biotite granite close to the contact with the sedimentary rocks.

The Sn granites from the Bujang Melaka pluton are similar to many other tin granites in the concentrating of Sn by fractional crystallization and by fluid-rock interaction. However, the outstanding feature of the pluton is the high level from which this concentration process started, as demonstrated by the high content of Sn in the megacrystic medium-grained biotite granite (27 ppm Sn). Most Sn granites in the world would have half this value or less at the same differentiation stage, taking their TiO_2 concentration as the differentiation index. The granite magma must have originated in a segment of the crust which was already enriched in Sn. (From authors' abstract by E.R.)

SCHWARZ, Dietmar and EIDT, Thomas, 1989, The Brazilian emeralds and their occurrences: Carnaíba, Bahia: J. Gemm., v. 21, no. 8, p. 474-486. First author at German Academic Exchange Service, Gemmological Centre, Federal Univ. Ouro Preto, Minas Gerais, Brazil.

Illustrates and discusses the two-phase and multiphase fluid inclusions observed in these emeralds. (H.E.B.)

SCOTT, G.L., 1988, The fluid-rock interaction history of the Tongonan geothermal field, Leyte, Philippines: Ph.D. dissertation, Univ. Auckland.

The Tongonan geothermal field, west Leyte, has been penetrated by 52 wells as deep as 2.6 km. The field presently produces an average of 60 MW_e from the Mahiao (western) and Sambaloran (central) sectors of the field. Exploitation of the Malitbog (eastern) sector is under consideration. The well P profiles show that upwelling of geothermal fluids occurs in the Sambaloran sector. The measured T profiles demonstrate that the regional ground-water flow is from the northeast. Cores and cuttings recovered during drilling have allowed a detailed petrographic, geochemical and isotopic study of the reservoir rocks which has led to the development of a model for the water-rock interaction history of the field. Chronological development of the field's evolution is believed to be as follows.

The extensive tholeiitic basalt and andesite volcanism and plutonism which occurred along a major structural feature in the Philippines, the Philippine Fault, in the Tongonan region in the mid- to late-Tertiary produced the Bao Volcanic Formation and the Mahiao Plutonic Complex. The Bao Volcanic Formation is composed of basalt and andesite lavas and volcaniclastic sediments interbedded with up to three thin horizons of shales and limestones containing Miocene fossils. Chemical and mineralogical evidence indicates that the Bao Volcanic Formation is the same composition as the gabbros and monzodiorites in the Mahiao Plutonic Complex.

When the magmas first intruded, they contact metamorphosed the overlying volcanics and plutonic basement rocks. The evidence for contact metamorphism is provided by electron microprobe analyses of biotite and actinolite in diorite cores from well 408; these have similar TiO_2 contents (3-5%) to the biotites, and Al_2O_3 contents (3-5%) to the actinolites present in contact metamorphosed rocks elsewhere. The geothermal system, which is inferred to have developed in the Miocene, was a low T (200-250°C), alkali chloride fluid type. This conclusion is based on (1) geothermometry of chlorites, epidotes, and illites, which formed at least 100°C below present-day T; and (2) the presence of these minerals in cores from well MN1 located 2 km outside the present field boundary.

In the Pliocene, the Philippine fault reactivated as a result of a westerly change in the direction of the Pacific plate. Uplift occurred at Tongonan while block faulting in the Philippine fault zone south in the Bao Valley coincided with intrusion of calc-alkaline granodiorite into the Malitbog sector. These magmas fractionated approximately equal proportions (30-40%) of plagioclase and hornblende, with lesser amounts of magnetite and apatite. Granodiorite magma did not reach the surface, but hornblende-dacite dikes in the Bao Volcanic Formation are subsurface manifestations of this magma.

As the granodiorite intruded and crystallised, large (≈2 mole %) amounts of gas (mainly CO_2, but also H_2S) in geothermal steam dissociated to form a corrosive acidic condensate which intensely altered the host rocks and deposited kaolinite, alunite, pyrophyllite and diaspore to depths of about 500 m below sea level. Evidence for past gassy boiling fluids in the western (Malitbog) sector is provided by the extensive relict acid alteration there, the absence of zeolites, and fluid inclusion observations (coexisting liquid- and vapour-rich inclusions and positive internal P identified during crushing).

Epidote, illite, chlorite, quartz, anhydrite and garnet deposited from boiling, neutral pH, alkali-chloride, geothermal waters in the deep reservoir. These exchanged O isotopes with the reservoir rock. The salinity of this fluid has not changed significantly because Tm(ice) of fluid inclusions (mainly in anhydrite) are approximately constant (≈2 wt % NaCl eq.) and the same as the present-day deep fluid concentration. Comparison of Th on fluid inclusions with measured T suggests that the entire field has cooled by an average of about 30°C since the Pliocene.

In the Quaternary, calc-alkaline granites intruded the basement rocks in the Mahiao sector. The gas released from this magma may account for the higher (≈0.3 mole % CO_2) gas concentrations in the Mahiao relative to the Malitbog fluids. Steam condensation also caused acid alteration in the Mahiao sector, but this is less extensive here than in the Malitbog. The deep neutral-pH fluids deposited quartz and lesser albite, adularia, wairakite, apatite, fluorite, talc, anhydrite, calcite, illite, chlorite, prehnite, epidote, pyrite, and base metal sulphides, and exchanged oxygen isotopes with the rock, probably during the Pleistocene. The present-day deep fluid discharging from wells has deuterium and oxygen isotope compositions of -35‰ and -1‰, respectively, and is not in isotopic equilibrium with the reservoir rock (+3‰ for O_2) at 330°C in the centre of the field. Na (present as albite) enrichment of the basement rock occurred at high T (>250°C) in the Mahiao, while Ca and K (present as calc-silicates and calcite, and illite) enrichment occurred in the Bao Volcanic Formation at low T (<250°C). The chemistry of Holocene fluids (e.g., 10,000 mg/kg) was much the same as the chemistry of the Pleistocene except that the CO_2 content of the gas discharging through the Tongonan geothermal system is lower (<0.4 mole %) now. (Author's abstract)

SCOTT, P.W. and **DRAKOPOULOS, Y.D.**, 1989, An occurrence of barytes in the Wagwater Group near Irish Town, St. Andrew: J. Geol. Soc. Jamaica, v. 26, p. 19-21.

Indexed under FI. (E.R.)

SEAL, R.R., II and **RYE, R.O.**, 1989, Isotopic modeling of meteoric water-rock interactions, Bayhorse (Cu-Pb-Ag) district, Idaho (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A150. First author at Dept. Geological Sciences, Univ. Michigan, Ann Arbor, MI 48109.

The Bayhorse district provides a unique opportunity to model base- and precious-metal mineralization solely produced through meteoric water-rock interactions. The small size of the hydrothermal system and resulting orebodies, the isotopically light ancient meteoric waters ($\delta D = -140‰$) and the isotopically varied metasedimentary carbonates, slates and phyllites are ideal for deciphering the details of water-rock interactions. The ores are located near the Nevada Mtn. stock and are hosted by the Ramshorn Slate and Bayhorse Dolomite, above the Garden Creek (GC) Phyllite and Dolomite. The ores are typified by two mineral associations: Stage I, siderite + tetrahedrite; and Stage II, quartz + galena. Stage I fills veins within the Ramshorn Slate; Stage II either follows Stage I in the veins or fills breccias within the Bayhorse Dolomite. Ore deposition was contemporaneous with the intrusion (ca. 97 Ma) and formed from hot (205 to 376°C), CO_2-bearing brines (5 to 20 eq. wt % NaCl). The $\delta^{18}O(H_2O)$ values for Stages I and II range from 8.4 to 11.2, and from 3.9 to 8.3‰, respectively. Stage I $\delta D(H_2O)$values vary from -55 to -95‰. Stage II values range from -112 to -146‰ and indicate a major meteoric contribution. Whole-rock $\delta^{18}O$ and δD values from the GC Phyllite define an isotopically depleted zone (75 km^2) around the stock and are modeled to be the result of high T interactions with ancient meteoric waters at low W/R ratios. Interactions between meteoric waters and phyllite best describe Stage I fluids and indicate low W/R ratios (0.002 to 0.02), consistent with the whole-rock isotopic data. Stage II fluids are heavier than predicted values and require interactions with the GC dolomite at slightly higher W/R ratios (0.09 to 0.03). The $\delta^{13}C(CO_2)$ values for Stage I (calculated from siderite; -9.1 to -7.4‰) suggest derivation from organic matter in the GC Phyllite (-23.6 to -20.9‰), while Stage II values (from fluid inclusions; -4.0 to -1.8‰) are most similar to the GC Dolomite (-2.3 to -2.2‰). Thus, the $\delta^{13}C$ data support early, phyllite-dominated water-rock interactions at low W/R giving way to later, dolomite-dominated interactions at higher W/R. This study demonstrates that meteoric water-rock interactions could account for all the isotopic variations observed in the P ore fluids, and by implication, for the source of most fluid components. (Authors' abstract)

SECCOMBE, P.K. and **BRILL, B.A.**, 1989, Fluid inclusion and S, O, H, and C isotopic evidence for metamorphic Cu, Zn, Pb, and Au ore formation at Cobar, New South Wales, Australia (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-66-67. First author at Univ. Newcastle, New South Wales, Australia.

Cu-Zn-Pb, Cu-Au, and Zn-Pb vein and discordant massive deposits in the Cobar region, New South Wales, are hosted by multiply deformed Early Devonian turbidites. Microthermometry and laser Raman spectroscopy of inclusion fluids from vein quartz and calcite associated with all styles of mineralization indicate three principal inclusion types: (1) low salinity (less than 2 wt % NaCl eq.), aqueous, mixed CO_2 and CH_4 type (low total CO_2 content; CO_2:CH_4 ratios in the gas phase range from 9:1 to 7:3), (2) CH_4-rich type, and (3) low salinity, aqueous type.

Th and inclusion types are similar for individual deposits. Type 1 and 2 inclusions from the CSA Cu-Zn-Pb vein deposit yield an average Th of 305°C for quartz and 273°C for calcite. Type 1 inclusions for the central mineralized area (principal deposits are New Cobar, Chesney, Occidental, Queen Bee, Great Cobar) indicate a range in average Th from 215°C to 325°C. Type 1 inclusions in quartz from the massive Zn-Pb Elura deposit average 320°C. Average Th measurements on type 3 inclusions in barren quartz from the central area and from nonmineralized syntectonic extension veins adjacent to the Elura deposit range from 146°C to 190°C.

Type 1 fluids are considered to have been trapped close to the solvus of the H_2O-CO_2-CH_4-(NaCl) system and hence Th approximates Tt. Type 2 inclusions are associated with Pb-Zn mineralization and late chlorite shears in the CSA Mine and may represent a separate, low CO_2 ore fluid trapped late in the paragenesis. Th data for Type 3 inclusions require a T correction of ~+160°C, which corresponds to the metamorphic load of 2.5-3 kbars and indicates a T range from 300°C to 350°C for metamorphic fluids present during sub-vertical extension of the Cobar orebodies.

The calculated isotopic composition of the CSA mine ore fluid is $\delta^{18}O_{V\text{-}SMOW}$ = +3.7 to +5.5‰, $\delta^{13}C_{V\text{-}PDB}$ = -6.3 to 6.7‰, and the measured isotopic composition of fluid inclusions is $\delta D_{V\text{-}SMOW}$ = -42 to -44‰. The calculated isotopic composition of the regional metamorphic fluid is $\delta^{18}O_{V\text{-}SMOW}$ = +5.1 to +6.8‰, $\delta^{13}C_{V\text{-}PDB}$ = -4.4 to -6.7‰, and $\delta D_{V\text{-}SMOW}$ = -33 to -38‰.

The fluid inclusion and isotopic studies strongly support structural, textural, and mineral chemical evidence that indicate a metamorphic origin for all of the Cobar orebodies. Metal and sulfur appear to have been derived from the Cobar Supergroup sedimentary pile during early metamorphic dewatering. (From authors' abstract by E.R.)

SECCOMBE, P.K. and **HICKS, M.N.**, 1989a, The Hill End goldfield, NSW Australia—Early metamorphic deposition of auriferous quartz veins: Mineralogy and Petrology, v. 40, p. 257-273. Authors at Dept. Geology, Univ. Newcastle, Australia.

Gold-bearing quartz veins in the Hill End goldfield, NSW Australia, comprise bedding parallel vein sets and lesser cleavage parallel and fault controlled veins which are hosted by a multiply deformed Late Silurian slate-metagreywacke turbidite sequence. Open to ptygmatic folds and boudinage are characteristic features of the veins. Metamorphic P, T estimates of 2.9 kb and 420°C during Early Carboniferous deformation and vein emplacement are obtained from the calcite, ferroan-magnesian calcite geothermometer and the Si-content of white mica. Fluid inclusions from vein quartz represent unmixed H_2O-rich and CO_2-rich low salinity fluids which have been trapped close to the solvus of the H_2O-CO_2-(NaCl-CH_4) system. Th (range 260-361°C) therefore represent true Tt. A preliminary sulphur isotope study of the vein sulphides indicates that the underlying turbidite sequence has acted as a source of sulphur (range -2.8 to 17.8‰). Formation of most veins early in the deformation and the lack of an obvious igneous intrusive source suggests that the Au, as for the sulphur, has been derived from the metasedimentary sequence. Deposition of Au has resulted from complex destablisation due to H_2S loss during transient vein opening and fluid pH changes accompanying CO_2-consuming wallrock reactions. (Authors' abstract)

SECCOMBE, P.K. and **HICKS, M.N.**, 1989b, Isotopic and geochemical modeling of early metamorphic turbidite-hosted gold mineralization at Hill End, New South Wales, Australia (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-66. Authors at Univ. Newcastle, New South Wales, Australia.

Au-bearing quartz veins in the Hawkins Hill area of the Hill End Au field, New South Wales, comprise bedding-parallel vein sets that are hosted by a multiple deformed Late Silurian slate-metagraywacke turbidite sequence. The veins are localized close to the crest of the Hill End Anticline sequence. The veins are localized close to the crest of the Hill End Anticline and formed in response to slip mechanisms operating during the early stages of Early

Carboniferous greenschist facies metamorphism. Tight to ptygmatic folds and boudinage are characteristic features of the veins. Vein emplacement is accompanied by a narrow zone of chlorite and white mica wallrock alteration and more extensive carbonate (calcite, ferroan-magnesium calcite, and ankerite).

P-T estimates of 2.9 kbars and 420°C during vein emplacement and metamorphism are obtained from the calcite, ferroan-magnesian calcite geothermometer and the Si content of white mica.

Fluid inclusions from vein quartz are commonly three phase $CO_2(l)$-$CO_2(g)$-$H_2O(l)$ types with variable L-V ratios. High CO_2 contents and probable additional CH_4 are argued from depressed Tm CO_2 (x = -57.1°C) and slightly elevated Tm CO_2 hydrate (x = 10.1°C) when compared with the pure CO_2-H_2O system. Tm ice (X = -1.6°C) indicate a maximum salinity of 2.5 wt % NaCl eq. Th for both liquid- and vapor-rich inclusions are similar (x = 343°C; range = 260° to 361°C; n = 133). The ore forming fluid is likely to have been trapped as two unmixed low salinity fluids (one CO_2-rich, the other H_2O-rich) close to the solvus in the H_2O-CO_2 (NaCl, CH_4) system. Th therefore may be close to the true Tt.

A preliminary sulfur isotope study of the vein sulfides suggests that the underlying turbidite sequence has acted as a source of sulfur ($\delta^{34}S$ for vein sulfides: (x = 6.7‰; range -2.8 to 17.8‰; n = 7).

The timing of vein formation and the lack of an obvious igneous intrusive source suggests that Au, as for S, may have been derived from the sedimentary sequence. However, an alternative model may be viable, based on the extraction of Au from a probable underlying shoshonitic basaltic-andesite sequence representing a rifted Ordovician island arc. An isotopic study of trace Pb in Au and associated sulfides is underway to discriminate between these two possible sources of Au. Deposition of Au at Hill End has taken place in apparent response to redox changes in the ore fluids resulting from CO_2-consuming wallrock alteration reactions and CO_2 and H_2O loss through transient pressure drops during the crack-seal cycle of vein formation. (Authors' abstract)

SEDLETSKIY, V.I. (ed.), 1988, Mineral formation from boiling solutions: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., 200 copies printed, 116 pp. (in Russian).

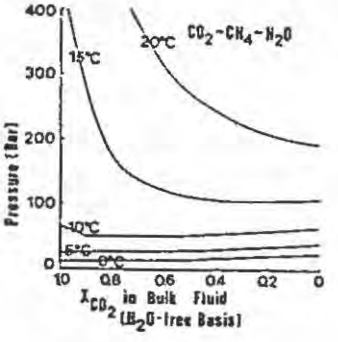
The book contains 71 abstracts of lectures, part of which present data on fluid inclusions. The latter are included in this volume alphabetically by authors' names. (A.K.)

SEEWALD, J.S. and **SEYFRIED, W.E., Jr.**, 1989, Organic-rich sediment alteration: Experimental and theoretical constraints on the chemistry of hot-spring fluids at Guaymas Basin, Gulf of California (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A49.

SEITZ, J.C. and **PASTERIS, J.D.**, 1989, Theoretical and practical aspects of differential partitioning of gases by clathrate hydrates in fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 58. Authors at Dept. Earth and Planet. Sci. and McDonnell Center for Space Sci., Washington Univ., Campus Box 1169, St. Louis, MO 63130.

During microthermometric analysis (MT) of aqueous gas-rich FI, clathrate hydrates commonly form at low T. Formation of a clathrate hydrate may complicate MT interpretation due to differential partitioning of two or more gas species between clathrate and fluid: Low-T phase equilibria may represent the *residual gas* component after enclathration and *not* the *bulk fluid* in the inclusion. To account for the presence of a clathrate hydrate during MT, we have used the model of John et al (1985) for clathrate equilibria, which predicts the direction and extent of differential partitioning of gases between clathrate and fluid. Langmuir constants (incorporability factors) are calculated for each gas species in the different sites in the clathrate structure as a function of T. Partitioning of gas into the clathrate is then a function of a Langmuir constants and fugacities of the gas species at Tmc. A T-cycling technique is suggested, because the sluggish kinetics of the clathrate make it unable to reequilibrate rapidly at lower T. The partitioning of the individual gas species into the clathrate hydrate at this T indicates the direction and extent of relative depletion/enrichment of the gas species in the residual fluid after enclathration. For any given Tmc, the relative partitioning of two gas species between clathrate and residual fluid is qualitatively indicated by the dissociation P of the endmember clathrates. For example, in the figure, the positive slope of 0°C and 5°C Tmc isotherms indicates that CO_2 is preferentially partitioned into the clathrate relative to CH_4 for all bulk fluid compositions (i.e., residual liquid is CH_4-enriched). The 10°C isotherm is more horizontal and exhibits a binary P minimum, at which point the $X(CO_2)$ of the clathrate is the same as that of the bulk inclusion. The direction of partitioning reverses across a binary P minimum, as reflected by the change in slope. For Tmc's above 10°C, the dissociation P of CO_2 clathrate becomes a sensitive function of T, increasing dramatically, as exhibited by the 15° and 20°C isotherms. The change to a negative slope indicates that CH_4 is preferentially partitioned into the clathrate relative to CO_2 at Tmc's somewhat above 10°C. This partitioning reversal is reflected in the crossover (in P-T space) of the dissociation/melting curves of pure CH_4 and pure CO_2 clathrates (Burruss, 1981, p. 60). For any binary gas clathrate system for which data like those in the figure can be calculated, simple determination of Tmc indicates whether the residual fluid will be enriched in species A or B. For the CO_2-CH_4-clathrate system (see figure), at low Tmc, the dissociation P of the clathrate is not sensitive even to large compositional variations. However, at higher Tmc's, even small additions of CH_4 to CO_2-dominant clathrate produces a very large shift in dissociation P. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p.347-348. (E.R.)



SEITZ, J.C., PASTERIS, J.D. and **CHOU, I-M.**, 1989, Quantitative composition and density determination of CH_4-N_2-bearing fluid inclusions by Raman micro-spectroscopy (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A358. First author at Dept. Geological Sciences, Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

A laser Raman microprobe (LRM) has been used to quantitatively determine both the composition and *density* of individual fluid inclusions containing CH_4 and N_2. These data are essential for the estimation of the P and T of trapping of the fluid. Previously, density determination of compositionally complex fluid inclusions was available only from microthermometric (MT) data. Through use of a high-P gas cell, we have (1) calibrated an LRM for accurate quantitative compositional analysis, and (2) determined the P- and composition-sensitivity of the spectral band positions for pure CH_4 and N_2 and for their mixtures of known composition at measured P up to 690 bars. These calibrated parameters have been applied to natural CH_4-N_2 fluid inclusions from the Duluth Complex, Minnesota, whose compositions (extremely low freezing temperatures) and small size make accurate MT analysis very difficult. One of the products of our calibration method is that, for a specific gas mixture, we can interpret the spectral positions of CH_4 and N_2 in terms of the partial P of the individual gases, the sum of which represents the total internal P in an inclusions. The total gas P also may be calculated from determination of the partial P of one of the components coupled with its relative abundance obtained from Raman peak area ratios. For the inclusions (CH_4-N_2) under study, the total internal P (240-490 bars) calculated by the two different methods agree very well. The consistency of the data indicates the validity of our calibration method and its applicability to natural inclusions. More importantly, accurate determination of both the composition and total internal P of fluid inclusions by LRM (with its inherent advantages over MT) permits the densities of inclusions to be determined. (Authors' abstract)

SELLWOOD, B.W., SHEPHERD, T.J., EVANS, M.R. and **JAMES, B.**, 1989, Origin of late cements in oolitic reservoir facies: A fluid inclusion and isotopic study (Mid-Jurassic, southern England): Sediment. Geol., v. 61, p. 223-237. First author at Postgraduate Research Inst. for Sedimentology, The Univ., P.O. Box 227, Whiteknights, Reading RG6 2AB, U.K.

During Bathonian times a carbonate ramp was constructed over southern England by the progradation of oolitic, skeletal and oncoidal grainstones and packstones. The grainstones provide a significant hydrocarbon reservoir facies. Although these carbonates suffered early diagenesis under marine and, more significantly, meteoric conditions, later diagenetic cements such as saddle dolomite and, more particularly, mildly ferroan calcite are volumetrically more important in causing the occlusion of porosity on a regional scale. We have analyzed systematically these late cements employing a number of techniques: standard petrography (including CL and UVL); C and O isotopes; Sr isotopes and FI studies. Integration of the results of these approaches constrains both the pore-fluid composition and the T regime at the time of cement precipitation. Saddle dolomite was emplaced before the mildly ferroan calcite at T between 75 and 85°C and from highly saline brines (18-19.5 wt % NaCl eq.). Mildly ferroan calcite precipitated over a generally lower T range and for less saline brines (6.5-15 wt % NaCl eq.). Five types of FI have been recognized: (1)

monophase aqueous (L); (2) monophase oil (L); (3) two-phase aqueous (L + V); (4) two-phase oil (L hydrocarbon + V); (5) three-phase aqueous-oil (L hydrocarbon + aqueous L + V). During burial warm (>75°C) brines passed through the limestones and precipitated saddle dolomite. Later, slightly cooler oil-rich brines precipitated mildly ferroan calcite wherever hydrocarbon accumulation had not already occurred. Our S isotopic studies suggest that both these brines were derived from underlying, and more deeply, buried Lias shales and that these brines were generated from Late Jurassic times onwards. Brine movements are likely to have been largely complete by the Late Cretaceous. (Authors' abstract)

SEWARD, T.M., 1989, The hydrothermal chemistry of gold and its implications for ore formation: Boiling and conductive cooling as examples, *in* R.R. Keays, W.R.H. Ramsay and D.I. Groves, eds., The Geology of Gold Deposits: The Perspective in 1988: The Economic Geol. Publ. Co., p. 398-404. Author at Chem. Division, D.S.I.R., Private Bag, Petone, New Zealand.

The solubility of Au has been calculated in the high-T (290°C) hydrothermal fluids of the Ohaaki-Broadlands geothermal system. If the dihydrosulfidogold(I) complex $(Au(HS)_2^-$ is assumed to account for the Au in solution, the calculated solubility is 11.1 $\mu g\ kg^{-1}$ which is in reasonable agreement with the measured value of 1.5 $\mu g\ kg^{-1}$. The concentration of Au in solution as $AuCl_2^-$ is very small (1.2×10^{-7} $\mu g\ kg^{-1}$) and this species is unimportant in the transport of Au in these ore-forming fluids. If Au is present in solution as $(Au(HS)_2^-$, single-step adiabatic flashing of the Ohaaki-Broadlands deep fluids (t = 290°C) leads initially to an increase in Au solubility, thus preventing Au precipitation until a T of 277°C is reached. If, however, the gas phase is removed (open system) at any intermediate T between 290° and 277°C, the Au solubility drops rapidly with further boiling and phase separation with Au deposition occurring within 5° to 10°C of the fractionation T. By contrast, simple conductive cooling causes immediate minor Au precipitation but does not lead to the dumping of essentially all the Au in solution over a small T interval. It has also been shown that with fluid fluxes characteristic of active hydrothermal systems, 10^6 oz of gold may be transported into the boiling zone of an ore-depositing system over short periods of less than 1,000 years. (Author's abstract)

SHA, Peng, 1989, Microthermometry of fluid inclusions in auriferous quartz veins from Hog Mountain and Goldville district, northern Piedmont, Alabama (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A286. Author at Dept. Geology, Univ. Alabama, Tuscaloosa, AL 35487.

Vein quartz from the tonalite-hosted Au mine at Hog Mountain and two metapelite-hosted Au mines in the Goldville district, northern Alabama, contains numerous fluid inclusions that can be classified into five compositional types:

(1) H_2O(liq.) + CO_2(liq.) + CO_2(vap.) + solid(s);
(2) H_2O(liq). + H_2O(vap.) + solid(s);
(3) H_2O(liq.) + H_2O(vap.);
(4) H_2O(liq.) + CO_2(liq.) + CO_2(vap.); and
(5) CO_2(liq.).

Both P and S fluid inclusions, formed during four hydrothermal stages, have been recognized on the basis of the petrographic characteristics and cross-cutting relationships in the Goldville district; but only S fluid inclusions, formed in one stage, have been identified at Hog Mountain.

H_2O, CO_2, NaCl, $MgCl_2$, and CH_4 are recognized as the main chemical components of the hydrothermal fluids by the microthermometry study. The measured and calculated physiochemical conditions of the fluids vary greatly: Th = 350-75°C, salinity = 36.5-0.2 wt %, $fO_2 = -10^{-35}$-10^{-39}, density = 1.45-0.85 g cm^{-3} for the Goldville district; Th = 350-100°C, salinity = 21.8-0.3 wt %, density = 1.1-0.75 g cm^{-3} for Hog Mountain. Different generations of fluid inclusions and multiple fluid sources (magmatic, metamorphic, and meteoric) are interpreted to contribute to this variation for the Goldville district and Hog Mountain, respectively.

Microscopic studies indicate that S fluid inclusions (early stage at the Goldville district) formed simultaneously with sulfides, the interpreted Au-bearing minerals in the veins. The observed variations in the physiochemical conditions of the fluids may have influenced the deposition of sulfides and Au. (Author's abstract)

SHADAKSHARA, S.N. and **MANJUNATHA, R.B.,** 1989, Geothermometry of ultramafic rocks around Terakanambi, southern Karnataka: Current Science, v. 58(9), p. 494-495.

Indexed under FI. (E.R.)

SHAIKH, A.M. and **SHEARMAN, D.J.,** 1986, On ikaite and the morphology of its pseudomorphs: Proc. Int'l Meeting on Geochemistry of the Earth Surface and Processes of Mineral Formation, Granada, Spain, p. 791-803. First author at Geology Dept., Kuwait Univ.

Crystals of ikaite, $CaCO_3 \cdot 6H_2O$, were grown in the laboratory and allowed to break down at normal temperatures to see whether calcite pseudomorphs could be formed. Two crystal habits grew in the course of the experiments, and both became pseudomorphed [by] calcium carbonate on decomposition. Crystals removed from their parent solution and brought to normal laboratory conditions rapidly lost their water of crystallization and were replaced by a porous friable mixture of vaterite with minor proportions of calcite. In some instances release of water of crystallization in the early stages of alteration was accompanied by deep etching which obliterated crystal faces and produced a system of steps and facets. These deteriorated into ridges and furrows essentially similar to those observed on naturally occurring pseudomorphs. It is therefore suggested that the aberrant morphologies of calcite pseudomorphs of ikaite may be the result of self etching caused by release of water of crystallization during the diagenetic breakdown of the parent crystals. (Authors' abstract)

This mineral might be formed in certain inclusions on cooling (see also Shearman et al., 1989, this volume). (E.R.)

SHANKS, W.C., III and **CRISS, R.E.** (eds.), 1989, New frontiers in stable isotopic research: Laser probes, ion probes, and small-sample analysis: U.S. Geol. Survey Bull. 1890, 174 pp.

The result of a workshop held in Reston, Virginia, January 12-13, 1988; contains 13 papers that discuss laser microprobe and ion microprobe analysis techniques used on geological samples for stable and rare gas isotopic ratios.

SHARASKIN, A.Ya., KAMENETSKY, V.S., SUSHCHEVSKAYA, T.M. and **KNYAZEVA, S.N.,** 1989, Hydrothermal paratakamite-quartz mineralization in metabasalts of oceanic crust: Dokl. Akad. Nauk SSSR, v. 304, no. 3, p. 714-716 (in Russian). First author at Geol. Inst. of Acad. Sci., Moscow, U.S.S.R.

A new type of mineralization was found on dredging a tectonic cliff in the slope/flank transition zone of the Mid-Atlantic Ridge (3°11'S, 9°39'W; depth 3700-4200 m). The samples studied are breccias, composed of metabasalt fragments, cemented by finely crushed material of these rocks and their alteration products. Some samples are crossed by quartz veinlets with a dark green mineral, determined by X-ray as paratakamite, $Cu_2(OH)_3Cl$. The other ore phase is black to brown and glassy, with a variable composition (by EMPA) (wt %) Fe—57.6-69.3; Si—3.0-15.6; Cu—0.9-4.3; Cl—0.1-2.1; Na—0.1-3.7; P—0.2-1.2. It is supposed that this phase has replaced goethite that formed after pyrrhotite.

Table 1. Composition of fluid inclusions in quartz.

Component	Concentration, g/l		Component ratios		
	1	2	component	1	2
Na	40.2	10.4	Na/K	6.1	26.0
K	6.6	0.4	Na/Ca	1.5	26.0
Ca	26.6	0.4	Ca/Mg	4.0	0.3
Mg	6.6	1.3	Cl/F	8.4	***
Cl	30.2	19.4			
F	3.6	10^{-3}			
CO_2*	135.1				
CH_4*	trace				
H_2O	0.1**				

1—sample N 5P-D47; 2—oceanic water, T-20°C, S-35‰.

*soluble gases in homogeneous fluid; **water content, wt %; *** "1.9×10^5" in original, but apparently should be 1.9×10^4 (E.R.).

The T and chemical composition of mineral-forming fluids were found by determination of (a) Th of fluid inclusions in quartz, (b) salt concentrations of water leachates of inclusion solutions (by AAS for cations and by liquid chromatography for anions), (c) gas and H_2O contents (by gas chromatography with thermal decrepitation of inclusions).

Comparison of the results for fluid inclusions with oceanic water data (Table 1), and Th values (220-260°C), indicate a hydrothermal origin for the quartz. On the basis of ore phase composition and very high content of chloride in fluid, we conclude that this mineral association formed as a result of heated fluid circulation in deep horizons of oceanic crust. (Abstract by T. Sushchevskaya)

SHARP, Z.D., HELFFRICH, G.R., BOHLEN, S.R. and ESSENE, E.J., 1989, The stability of sodalite in the system $NaAlSiO_4$-NaCl: Geochim. Cosmochim. Acta, v. 53, p. 1943-1954. First author at Geophysical Laboratory, Carnegie Institution of Washington, 2801 Upton Street, N.W., Washington, D.C. 20008.

The reaction sodalite = β-nepheline + NaCl (*s*) was reversed in solid-medium apparatus (923 K, 7.6-8.0 kbar; 973 K, 7.4-7.6 kbar, 1073 K, 7.8-8.0 kbar; 1173 K, 8.4-8.6 kbar) and the reaction sodalite = carnegieite + NaCl (*l*) was reversed at 1 bar (1649-1652 K).

Sodalite is a high-T, low-P phase, stable well above the solidus in sodic silica-undersaturated magmas enriched in NaCl, and its presence constrains NaCl activities in magmas. Estimates of minimum NaCl (*l*) activities in the Mont St-Hilaire sodalite syenites are 0.05 at 1073 K and 0.13 at 1273 K. Density calculations are consistent with the field observations that sodalite phenocrysts will float in a nepheline syenite liquid. This explains the enrichment of sodalite in the upper levels of the sodalite syenites at Mont St-Hilaire and elsewhere. (From authors' abstract by E.R.)

SHAULKIN, V.V., 1988, Decrepitation of gas-liquid inclusions in minerals: Zap. Vses. Mineral. O-va., v. 117(4), p. 488-493 (in Russian). Author at Nauchno-Proizvod. Ob'edin. "Rudgeofizika," U.S.S.R.

A theor. model is proposed for characterization of decrepitation of FI in minerals, based on the relation between crit. stresses inducing mineral rupturing and the dimensions of the FI. The crit. value (K) of the coeff. of stress intensity is related to the crit. stress (σ) and the half-length of FI (*l*) by the equation $K = \sigma \sqrt{l}$. Graphical representations of the model (theor. decrepitograms) are given for FI in quartz, for cases of FI with water or with CO_2, with coeff. of filling (F) 0.7 or 0.8, and with exponential or lognormal size distribution. In general the shape of the decrepitograms for a particular mineral will be detd. by the distribution at high T of those FI which stand the crit. stresses. Difference of minerals in elastic properties and surface energy causes a difference in FI decrepitation, e.g., minerals with perfect cleavage have low σ values and decrepitation can begin at a uniform T when P creates crit. stresses, even before homogenization. Some conclusions drawn for actual decrepitograms are: (1) if the decrepitogram for a particular genetic group of FI takes the form of a single peak the range in size of FI is small and the F-X (fluid compn.) relation is fairly const. for the group and (2) if the decrepitogram is complex, with several extrema, FI of >1 genetic group are present. (CA 110:26749r)

SHCHERBAKOVA, M.N., MELNIKOV, F.P. and PRASOLOV, E.M., 1989, The gas-liquid inclusions in the natural glasses of Azerbaijan, *in* J. Konta, ed., Int. Conf. Nat. Glasses, 2nd 1987 (Pub. 1989), p. 149-154 (in English). Authors at Dept. Geology, Moscow Univ., 117234 Moscow, U.S.S.R.

The gas phase of gas-liq. (fluid) inclusions in volcanic glasses of Azerbaidzhan (USSR) is dominantly CO_2 and N_2 but also has H_2, CH_4, and Ar. The CO_2/CH_4 ratio is ~10, which is characteristic for magmatic fluids. The liq. is CO_2. The compn. of the gas phase suggests that the abiogenic formation of hydrocarbons occurred during past magmatic activity in the region. (CA 112:162342w)

SHEARMAN, D.J., McGUGAN, A., STEIN, C. and **SMITH, A.J.**, 1989, Ikaite, $CaCO_3 \cdot 6H_2O$, precursor of the thinolites in the Quaternary tufas and tufa mounds of the Lahontan and Mono Lake Basins, western United States: Geol. Soc. Am. Bull., v. 101, p. 913-917. First author at Dept. Geology, Imperial College, Prince Consort Rd., London SW7 2PB, U.K.

The thinolites in the Quaternary tufas and tufa mounds of the Lahontan and Mono Lake basins of the western United States are identified as being pseudomorphous after crystals of the mineral ikaite, $CaCO_3 \cdot 6H_2O$. Ikaite is a metastable mineral in the sedimentary realm. It crystallizes from solution at T close to zero Celsius but rapidly decomposes at warmer T and becomes pseudomorphed [by] calcite by *in situ* redistribution of the calcium and carbonate ions. The likely implication is that the thinolites record ice-cold episodes during deposition of the tufas. (Authors' abstract)

This mineral might be formed in certain inclusions on cooling (see also Shaikh and Shearman, 1986, this volume). (E.R.)

SHEETS, R.W., NYMAN, M.W., DRISCOLL, A.J., Jr., KNIGHT, C.L. and **BODNAR, R.J.**, 1989, Fluids associated with a shear zone hosted hydrothermal Pt-Au-Cu deposit: Fluid inclusion study of the New Rambler Deposit, S.E. Wyoming (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-70-71. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

The New Rambler Pt-Au-Cu deposit is located in the Medicine Bow Mountains, SE Wyoming, along an east trending splay of the Cheyenne belt where rocks of the Mullen Creek Mafic Complex (MCMC) are deformed by mylonitic and cataclastic shear zones and later brittle faults. Ore is localized at the intersection of 2 mylonite zones and a set of NW tending brittle fractures. Ore is hosted by severely altered and deformed metagabbroic rocks and occurs as irregular zones of enrichment.

A least three episodes of mineralization have been identified at the New Rambler deposit (McCallum et al., 1976, Econ. Geol., 71:1429). An early high T stage of base metal sulfides and magnetite is followed by at least one stage of Pt-bearing mineralization and later supergene enrichment of Au and Cu. Propylitic alteration occurs throughout the deposit, intensifying in the vicinity of the shear zones as exhibited by extensive chloritization and sausseritization. Silicification and sericitization occur in bands surrounding ore zones.

Quartz pods and veins associated with sulfide minerals from the main PGE-bearing stage of mineralization show abundant evidence of strain including core/mantle structures, undulouse extinction and subgrain development. Three compositional types of FI in the quartz pods and veins have been identified by microthermometry and Raman spectroscopy. Pure N_2 inclusions (Type 1) have a negative crystal shape and occur as clusters and along well healed fractures within relatively undeformed cores of quartz grains. No phase changes were observed in these inclusions during freezing. CO_2 inclusions (Type 2) are single phase at room T and have a similar texture and occurrence as type 1 inclusions; depressed melting T (Tm = -60.0 to -56.7°C) indicate the presence of N_2 and/or CH_4. Aqueous inclusions (Type 3) of varying salinities occur along well and poorly healed fractures which are commonly truncated by subgrain boundaries. Type 3 inclusions include two phase, liquid + vapor H_2O, and three phase, liquid + vapor H_2O with halite dxls, at room T. All inclusion types clearly predate subgrain development.

Models for the New Rambler deposit involve remobilization of PGE from the metagabbros of the MCMC by hydrothermal fluids and subsequent deposition into the dilatant zones produced during shearing. (Authors' abstract)

SHENBERGER, D.M. and **BARNES, H.L.**, 1989, Solubility of gold in aqueous sulfide solutions from 150 to 350°C: Geochim. Cosmochim. Acta, v. 53, p. 269-278. Authors at Ore Deposits Res. Sec., The Pennsylvania State Univ., University Park, PA 16802.

The solubility of Au was measured in aqueous sulfide solutions at pH from 3 to 8, 150° to 350°C, and at P determined by the liquid-vapor P of the solution, with oxidation state fixed or buffered by either sulfate-sulfide equilibria or $H_2(g)$. Au may be precipitated from solution by both pH and redox changes. In addition, deceasing the activity of sulfide in solution is an effective mechanism for Au deposition. Analysis of the effect of T on the solubility of Au shows that a decrease in T may increase or decrease solubility. Deposition by cooling depends upon the pH-oxidation state path of the solutions. (From authors' abstract by E.R.)

SHEPHERD, T.J., BOTTRELL, S.H. and MILLER, M.F., 1989, Fluid inclusion volatiles as an exploration guide to black shale hosted gold deposits, Dolgellau gold belt, North Wales, U.K. (abst.): 28th Int'l Geol. Cong. Abstracts. First author at Geochem. Directorate, British Geological Survey, 64-78 Grays Inn Road, London WC1X 8NG, U.K. [Paper presented at Congress but abstract omitted from Abstracts Volume; should be at p. 3-97. E.R.] See also similar item with different title in ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 84-85.

Mass spectrometric analysis of the fluid inclusion volatiles in Au-bearing vein quartz from the Dolgellau gold belt, North Wales, U.K., suggests a distinction can be made between auriferous and non-auriferous fluids.

The veins are emplaced in a thick sequence of low grade greenschist facies Cambrian sedimentary rocks and are only auriferous where hosted by graphitic lithologies. Some veins extend for more than 3 km, but all vary considerably in width. Geologically, the deposits belong to the widely recognized group "black shale-hosted Au deposits." Previous fluid inclusion studies using microthermometric and laser Raman techniques had shown that the auriferous quartz ores were deposited from H_2O-CH_4-CO_2 fluids at 300°-320°C and 1.6 kb. The estimated P-T conditions and fluid compositions are consistent with metamorphic dewatering of the Cambrian sediments at the close of the Caledonian orogeny.

The inclusion volatiles are released by thermal decrepitation at 550°C under vacuum and the evolved gases analyzed using a fast scanning quadrupole mass spectrometer. A maximum of 0.5 g of acid cleaned quartz is required per analysis, making it ideally suited to drill core material. Detection limits are as follows: speciation of non-condensable gases (CH_4, N_2, CO, H_2, Ar) $\simeq$ 0.1 µl; CO_2 and C_2H_6 = 0.1 µl; H_2O = 50 µg.

Samples of auriferous quartz from ore shoots at the Clogau-St. Davids and Gwynfynydd mines (the two most important mines with a total recorded production of 120,00 oz Au) are significantly enriched in CH_4 and N_2 compared to quartz from barren veins. Variation in the composition of inclusion volatiles strongly supports a spatial link between the distribution of high grade ore zones, the presence of graphitic shale wallrocks (Clogau Shales) and CH_4-N_2 fluids. Though methanoic fluids also characterize regional metamorphic quartz veins hosted by graphitic lithologies, they have appreciably lower $N_2/(CH_4 + CO_2 + N_2)$ ratios. During mineralization, carbon is released to the ore fluids as a result of fluid-graphite interaction, the process generating CH_4 and CO_2. However, it is the concomitant generation of N_2 due to the oxidation of NH_4^+ substitution in wallrock phyllosilicate minerals by the relatively oxidizing auriferous fluids that gives rise to the distinctive "CH_4-N_2" signature. At the P-T conditions defined, thermodynamic calculations show that in the presence of CO_2, NH_3 is unstable and readily oxidized to N_2: $C + H_2O + CO_2 + CH_4$; [and] $NH_3 + CO_2 = N_2 + CH_4 + H_2O$.

In view of the worldwide occurrence of black shale/schist hosted Au deposits, the recognition of fluid inclusions with enhanced levels of $CH_4 + N_2$ constitutes a potential geochemical signature for discriminating between auriferous and non-auriferous quartz veins during reconnaissance exploration surveys. (Authors' abstract)

SHEPPARD, S.M.F., 1989, The isotopic characterization of aqueous and leucogranitic crustal fluids, *in* D. Bridgwater (ed.), Fluid Movements—Element Transport and the Composition of the Deep Crust: Kluwer Academic Publishers, Dordrecht, The Netherlands, p. 245-263. Author at Centre de Recherches Pétrographiques et Géochimiques, B.P. 20, 54501 Vandoeuvre-lès-Nancy, France.

The H- and O-isotope characteristics of the principal water types—sea, meteoric, formation, organic, metamorphic magmatic and hydrothermal—are outlined. Sea and meteoric surface waters can be involved with deep crustal processes following their downward penetration, or by their upward infiltration after oceanic or continental subduction processes. Examples illustrate the identification of such water sources in deep crustal rocks.

The typically cold (<30°C) Na-Ca-Cl brines ± CH_4, etc. encountered at deep levels (>300 m) in shields often plot to the left of the meteoric water line. Many of these brines are mixtures of recent meteoric waters with ancient brines. The most saline and therefore least contaminated brines may sometimes be modified Precambrian hydrothermal fluids. They underwent low T retrograde isotopic exchange with their host rocks, and water/rock ratios were very small.

The importance of the release of hydrous fluids from sedimentary formations into overthrusted and hot crustal or mantle slabs is emphasized. Such fluids can become involved in fluid mixing processes and aid partial melting reactions. Coupled O-, Sr- and Nd-isotope variations in a High Himalaya leucogranite are shown to be related to comparable variations in the Tibetan Slab paragneisses which are considered to be equivalent to the underlying source rocks. These variations imply that (1) isotopic homogenization was ineffective on a submetric scale during diagenesis and metamorphism, (2) major convective circulation of fluids did not occur, and (3) the granite massif is composed of a large number of essentially independent batches of magma. They are a result of the differences in the mineralogical constitution of the sediments and the aging effects between sedimentation and anatexis. (Author's abstract)

SHERLOCK, R.L., 1989, A study of the third dimension in the Thunder Bay silver mines: Fluid inclusion and stable isotope results: MS thesis, Lakehead Univ., Thunder Bay, Ontario.

Historic drill core from the Shuniah mine and more recent drill core from the Keystone and Porcupine mines have provided the basis for a study of these past Ag-producing veins as a function of depth. Precipitation was initiated from a boiling fluid at >370°C. Cooling of the fluid and precipitation of calcite and sulfides followed generally at 100°C. Several episodes of deposition separated by fracturing events are evidenced. From fluid boiling T the depth of emplacement for the veins is 1 km with the P regime alternating between hydrostatic and lithostatic. The ore-depositing solutions appear, therefore, to have arisen from depth and deposited their ores in proximity to diabase sills, which cap the various vein systems, in response to hydrologic factors.

Stable isotope studies reveal that C in vein calcite was possibly derived from oxidation of amorphous C in the Gunflint and Rove Formations ($\delta^{13}C$ = -33‰), which host the Ag lodes. Calcite as well, does not occur at great depth in the vein systems. $\delta^{18}O$ in calcite increases with depth, from calculated negative to positive values, suggesting that the ore-depositing fluid was a basinal-type brine that became increasingly mixed with meteoric water towards the surface. Fluid salinities are low to moderate, but invariably undersaturated, also supporting mixing. The dominant salts are NaCl, $MgCl_2$ and to a lesser extent $CaCl_2$. (Author's abstract)

SHERLOCK, R.L. and **KISSIN, S.A.**, 1989, A study of the third dimension in the Thunder Bay silver veins: Fluid inclusion and stable isotope results (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-121-122. Authors at Dept. Geol., Lakehead Univ., Thunder Bay, Ontario P7B 5E1, Canada.

Essentially same abstract as previous item. (E.R.)

SHERWOOD LOLLAR, B., **FRAPE, S.K.**, **FRITZ, P.**, **MACKO, S.A.**, **WELHAN, J.A.** and **BLOMQVIST, R.**, 1989, Gas geochemistry and its relationship to brines of the Canadian and Fennoscandian Shield (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A316.

SHEVENELL, Lisa and **GOFF, Fraser**, 1989, Tritium in the fumarole condensates of the dacite dome and new hot springs of Loowit Canyon, Mount St. Helens, Washington (abst.): Eos, v. 70, p. 495.

SHI, Jixi, **LI, Benchao** and **FU, Jiamo**, 1989, Assessment of thermal evolution stages and oil-gas migration of carbonate source rocks of early Tertiary in eastern Sichuan, China, by organic inclusion analysis (abst.): AAPG Bull., v. 73, no. 3, p. 412. Authors at Acad. Sinica, P.R.C.

The Jianlinjiang Formation of early Tertiary in Sichuan, China, is a series of limestone and dolomite sediments deposited in a platform shoal environment. The diagenetic sequence and organic inclusions trapped in minerals of 95 samples from 20 drillings have been studied. At the late diagenetic stage, pale yellow organic inclusions consisted of liquid hydrocarbons disseminated in pore-infiltrating dolomite, and the Th of contemporaneous saline liquid inclusions possessing a low gas-liquid ratio was 86°C. This indicates the evolution of the organic matter had gone over the oil generating threshold and oil formation had initiated.

In the limestone formed at the late diagenetic stage, more brown-yellow organic inclusions were scattered and/or developed along with fissures, comprising 60-70% liquid hydrocarbons and 30-40% gaseous hydrocarbons. Contemporaneous saline liquid inclusions with gas-liquid ratios of 5-10% had Th of 90°-130°C. These findings show that the organic material had entered a high evolution stage and oil migration had taken place on a large scale.

At the late tectonism stage, a large quantity of brown-black organic inclusions, consisting mainly of gaseous hydrocarbons, existed in infiltrated secondary gypsum and calcite veins. The Th of the contemporaneous saline liquid inclusions with gas-liquid ratios of 10-15% were 138°-170°C, concentrated at 150°C, implying an evolution stage of postmaturation and a predominance of gas migration at 150°C. The thermal gradient was confirmed to be 3.1°C/100 m by inclusion analysis. Liquid hydrocarbons were formed at a depth of 2,903 m, and the depth for oil migration in large quantities is 3,548 m, whereas gas migration is at 4,338 m. The industrial reserve in this area is of the post-fissure type. The study results also reveal that the fissures in connection with oil and gas opened vertically along strike at 160°C and depth of 5,250 m when the fissures were open. These fissures were formed during the Himalayan Period. (Authors' abstract)

"Homogeneous temperature" in the original was changed to Th by E.R. (E.R.)

SHIBUE, Yasuhiro, 1989a, Fluid inclusion study on the Kawahira and Seikyu deposits in Shimane Prefecture, Shisou deposit in Hyogo Prefecture, and Sennou ore body of the Nakatatsu deposit in Fukui Prefecture—Saline fluid inclusions from some molybdenum deposits in Japan: Mining Geol., v. 39, no. 1, p. 33-44 (in Japanese; English abstract). Author at Geosci. Inst., Hyogo Univ. of Teacher Ed., Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

Th and salinities of FI in some minerals from the Kawahira and Seikyu deposits in Shimane Prefecture, Shisou deposit in Hyogo Prefecture, and Nakatatsu deposit in Fukui Prefecture were measured in order to evaluate physico-chemical conditions for the Mo mineralization, and to compare them with those for W and other metalliferous deposits in Japan.

Salt-bearing polyphase inclusions as well as liquid-rich two-phase inclusions are found in vein quartz from the Kawahira deposit, in pegmatitic quartz from the Shisou deposit, and in clinopyroxene from the Nakatatsu deposit. CO_2-bearing FI as well as liquid-rich two-phase inclusions are found in vein quartz from the Seikyu deposit.

FI in vein quartz from the Kawahira deposit show Th ranging from 215° to 390°C, and the salinities ranging from 3 to 37 wt % (NaCl eq.). Plots of Th against salinity of FI show two populations of inclusions. It is concluded that these two populations originated from incomplete mixing of saline solution with dilute one.

Th and salinities of FI from the Seikyu deposit range from 191° to 325°C, and from 4 to 18 wt % (NaCl eq.), respectively.

Data for the Shisou deposit show that Th ranges from 205° to 416°C, and that salinities range from 11 to 44 wt % (NaCl eq.).

FI in clinopyroxene, vein quartz, and calcite from the Sennou ore body of the Nakatatsu deposit show Th ranging from 342° to 520°C, from 170° to 467°, and from 140° to 397°, respectively. Salinities of FI in clinopyroxene, vein quartz, and calcite range from 2 to 50 wt % (NaCl eq.), from 1 to 15 wt % (NaCl eq.), and from 0 to 11 wt % (NaCl eq.), respectively. It is shown that clinopyroxene precipitated at higher T than quartz and calcite in veins. Plots of Th against salinity of FI show two populations of inclusions; one for the mineralization of clinopyroxene with large variation in salinity, and the other for the mineralization of quartz and calcite with large variation in T.

Compilation of FI data for Japanese Mo deposits shows that the hydrothermal solutions with high salinities are characteristic for Mo mineralization in Japan, compared with Japanese W and other metalliferous deposits. (Author's abstract)

SHIBUE, Yasuhiro, 1989b, Vapor-transport of tungsten under hydrothermal condition and its geologic application: J. Faculty of Science, Univ. Tokyo, Section II, v. 22, no. 1, p. 1-10. Author at Geoscience Inst., Hyogo Univ. of Teacher Education, Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

An experimental study on the vapor-transport of tungsten under hydrothermal condition is carried out in order to examine its volatility, and to compare this with those of base metals. The experiment is performed in autoclaves containing 20 wt % NaCl solution with a small amount of tungstic acid or base-metal (copper, lead or zinc) chlorides under the condition of the coexistence of V and L phases at 350° and 550°C. More than 1/10 and 1/3 of the initial amounts of tungstic acid are vaporized in 24 hr at 350° and 550°C, respectively. On the other hand, less than 1/10 of the initial amounts of the base-metal chlorides are vaporized at these T in 24 hr. It is suggested that significant amount of tungsten can be transported in V phase separated from L phase, compared with those of the base metals. A tentative and simple model for the enrichment of tungsten compared with the base metals in the hydrothermal solution is shown based on present results, relating to the separation of V phase from L phase in geological processes. (Author's abstract)

SHIBUE, Y., 1989c, Interpretation of fluid inclusion data on some deposits with use of a mixing diagram (abst.): Min. Geol., v. 39, p. 56 (in Japanese, translated by S. Taguchi). Author at Hyago Univ. of Education.

Mixing diagrams of high T saline solutions with dilute solutions were constructed, based on the thermodynamic data for NaCl solutions, and applied to some Cu-Pb-Zn vein type and skarn type ore deposits in Japan.

Th and salinity data from the vein type deposits, which were plotted on the diagram, are distributed on a dilution line of high T (<400°C) and high salinities (≤20 eq. wt % NaCl); therefore, dilution caused the cooling. Moreover, the data suggest no clear evidence for the presence of magmatic water.

Similar data on the skarn deposits indicate that there is no simple dilution trend, but that the original fluids had variable compositions [and] dilutents. (Author's abstract)

See also next item. (E.R.)

SHIBUE, Yasuhiro, 1989d, Mixing diagrams of hydrothermal solutions (up to 600°C, 1000 bars, and NaCl 60 wt %) and the application to the Fujigatani and Kiwada tungsten deposits in Japan: J. Min. Petr. Econ. Geol., v. 84, p. 105-116. Author at Geosci. Inst., Hyogo Univ. of Teacher Ed., Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

T-chloride mixing diagrams at 500 and 1000 bars, up to 600°C and 60 NaCl wt %, are constructed in order to understand the mixing behavior of saline and dilute hydrothermal solutions. On the basis of density data on NaCl solutions, these mixing diagrams are recast onto Th-chloride mixing diagrams for the practical applications to the interpretations of FI data.

T-chloride mixing diagrams as well as Th-chloride mixing diagrams indicate that the mixing of saline (<25 wt %) high-T solution with dilute low-T solution shows near-linear relationship between T (or Th) and chloride concentration. Larger decrease in T than that in concentration is found for the fluids with higher concentrations.

Th and salinity data for vein quartz from the Fujigantani and Kiwada W deposits are shown to be the indication for the mixing of saline high-T (7 wt % NaCl eq. and 360°C) solution with dilute low-T (2 wt % NaCl eq. and 250°C) solution. (Author's abstract)

SHIBUE, Y., 1989e, Mixing diagrams of hydrothermal solutions and their applications to some hydrothermal ore deposits in Japan: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 625-628. Author at Geoscience Institute, Hyogo Univ. of Teacher Education, Hyogo, Japan.

See previous item and Fluid Inclusion Research, v. 21, p. 360. (E.R.)

SHIKAZONO, Naotatsu and **MASATAKA, Nakata**, 1989, Mineralogic, geochemical and geological characteristics of Se and Fe-bearing epithermal gold deposits in Japan (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-99. First author at Univ. Tokyo, Tokyo, Japan.

A large number of epithermal Au deposits occur in Tertiary-Quaternary volcanic terranes in Japan. These deposits are generally accompanied by Se and Te mineralizations. Se-rich deposits are Te free and Cu poor, while Te-rich deposits are associated with small amounts of Se and Cu. In this paper, the characteristics of these Se-bearing and Te-bearing deposits are summarized.

Fluid inclusion Th for the stages of Se and Te mineralizations are 210-250°C and 230-270°C, respectively, though the data on Te-bearing deposits are scarce. No Th data on massive Te-bearing deposits are obtained. (From authors' abstract by E.R.)

SHINOHARA, Hiroshi, IIYAMA, J.T. and **MATSUO, Sadao**, 1989, Partition of chlorine compounds between silicate melt and hydrothermal solutions: I. Partition of NaCl-KCl: Geochim. Cosmochim. Acta, v. 53, p. 2617-2630. First author at Dept. Chemistry, Tokyo Institute of Technology, Meguro-ku 152, Tokyo, Japan.

The partition experiments of NaCl and KCl between silicate melts and aqueous chloride solutions were carried at 810°C in the P range from 0.6 to 6.0 kb. The chloride concentration in the melt (C_{Cl}^{m}) was constant in certain ranges of chloride concentration in the aqueous phase (C_{Cl}^{aq}) at 0.6 and 1.2 kb, which reveals the presence of V-L immiscibility of the aqueous solution. The variation diagram of C_{Cl}^{m} and C_{Cl}^{aq} can be applied to the study of aqueous phases as a new method. The partition ratio of chloride ($D_{Cl}^{m/aq} = C_{Cl}^{m}/C_{Cl}^{aq}$ exhibits a strong negative P dependence, which is attributed to the large negative partial molar volume of chlorides in the aqueous phase. The distribution coefficient of Na and K ($D^{m/aq}_{Na/K} = (C^{m}_{Na}/C^{m}_{K})/(C^{aq}_{Na}/C^{aq}_{K})$) is about 0.75 and has little P dependence at P >2.2 kb. The distribution coefficient, however, has a positive P dependence at P <1.2 kb. (Authors' abstract)

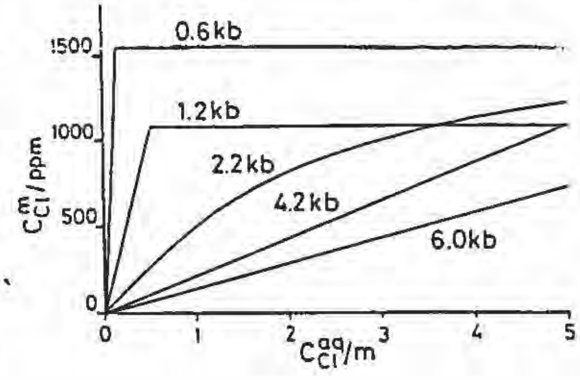
SHINOHARA, H., MATSUO, S. and **IIYAMA, J.T.,** 1989, Partition of chlorine compounds between silicate melt and hydrothermal solutions (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 240. First author at Inst. Tech., Dept. Chemistry, Meguro-ku, Tokyo 152, Japan.

Experimental partition equilibrium study of Cl compounds between silicate melt and Cl containing aqueous solutions was carried out at 810°C and in the P range from 0.6 to 6.0 kb. Synthesized glass with normative compositions ranging from Ab50,Or23,Q27 wt % to Ab40,Or17,Q40,C3 wt % was used as starting materials for silicate melts.

The relationship between chloride concentrations in the melt and in the aqueous phase varies with P, as shown in the figure. At 0.6 and 1.2 kb, the chloride concentration in the melt was constant in certain ranges of chloride concentration in the aqueous phase, which indicates the presence of V-L immiscibility of the aqueous solution. The relationship at 2.2 kb, which can be represented by a convex curve, may indicate non-ideal behavior of chlorides in the aqueous phase.

Partition ratio (D) of chlorides (NaCl+KCl) at infinite dilution (C in melt/C in aq, C:mol/kg) exhibits a strong negative P dependence (D = 0.30 at 0.6 kb and D = 0.004 at 6.0 kb), which is attributed to large negative partial molar volumes of alkali chlorides in the aqueous phase.

The ratio of HCl/(NaCl+KCl) in the aqueous phase is strongly controlled by the atomic ratio of Al/(Na+K) in the melt. For example, at 0.6 kb, the ratio HCl/(NaCl+KCl) = 0.003 was obtained in the aqueous phase equilibrated with the melt whose Al/(Na+K) ratio was unity, and HCl/(NaCl+KCl) was 10 in the aqueous phase equilibrated with the melt whose Al/(Na+K) = 1.1. When the ratio of Al/(Na+K) in the melt was fixed at 1.1, the HCl/(NaCl+KCl) ratio in the aqueous phase exhibits a strong negative P dependence (10 at 0.6 kb and 0.005 at 6.0 kb). (Authors' abstract)



SHOCK, E.L., 1989, Amino acid reaction rates and metastable equilibria in hydrothermal experiments (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A48.

SHOCK, E.L., HELGESON, H.C. and **SVERJENSKY, D.A.,** 1989, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Standard partial molal properties of inorganic neutral species: Geochim. Cosmochim. Acta, v. 53, p. 2157-2183. First author at Dept. Earth and Planetary Sciences, Washington Univ., St. Louis, MO 63130.

Consideration of interactions between neutral aqueous species and H_2O dipoles in terms of effective Born coefficients permits extension of revised equations of state for the standard partial molal properties of ionic species at high P and T to include inorganic gases, acids, and other neutral aqueous species. Close agreement between predicted and experimentally determined equilibrium constants for gas solubility and inorganic acid dissociation reactions at high T and P supports the validity and generality of the equations of state and the predictive algorithms. High T/P equilibrium constants can be predicted for reactions involving a wide variety of neutral aqueous species for which few or no experimental data are available at T >25°C. Present capabilities permit such predictions to be made for hydrothermal and magmatic conditions at P and T to 5 kb and 1000°C. (From authors' abstract by E.R.)

SHOCK, E.L. and **SVERJENSKY, D.A.**, 1989, Hydrothermal organometallic complexes of base metals (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A8.

SHUMLYANSKIY, V.A. and **SOKOLOV, V.D.**, 1989, New data on metallogeny of the Vendian cover formations of the SW margin of the Russian Platform: Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 187-191 (in Russian). First author at Inst. Geochem. and Physics of Minerals of Acad. Sci. of Ukrainian SSR, Kiev, Ukraine, USSR.

Stratiform fluorite, barite and polymetallic mineralization developed in Vendian sandstones, tuffs and tuffites of the Podolian and Volynian blocks yielded the following T (Th?-A.K.): Novosvetovskoe bitumen-fluorite deposit 325-70°C, Bakhtynskoe fluorite deposit 270-60°C, Kotovskoe barite-polymetal deposit 235-60°C, Dumbravenskoe barite-fluorite-sulfide deposit. Veinlets in crystalline basement gave 20-30°C higher T than contemporaneously formed veins and bodies in the sedimentary cover. The aqueous chloride mineral-forming solutions contained CO_2 and hydrocarbons. (A.K.)

SIANISIAN, E.S., 1988, Thermobarogeochemistry of the travertine formation: Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 90 (in Russian). Author at Rostov State Univ., Rostov, U.S.S.R.

Mineral fissures in travertines bear L and G/L inclusions filled by solutions of variable concentrations and sometimes by L hydrocarbons; Th and Td are also variable. (A.K.)

SIDDAIAH, N.S. and **RAJAMANI, V.**, 1989, The geologic setting, mineralogy, geochemistry, and genesis of gold deposits of the Archean Kolar schist belt, India: Econ. Geol., v. 84, p. 2155-2172. Authors at School of Environmental Sciences, Jawaharlal Nehru Univ., New Delhi 110 067, India.

The Kolar schist belt, one of the auriferous Archean schists belts in the Dharwar craton, includes two types of Au deposits: (1) a stratiform sulfide type, associated with amphibolites and banded ferruginous quartzite, and (2) a Au quartz-carbonate vein type associated with light rare earth element (LREE)-enriched komatitic and tholeiitic amphibolites on the eastern part of the belt. The sulfide lodes contain 5 to 30 vol % sulfides which include dominantly pyrrhotite and arsenopyrite. The lodes also contain variable amounts of magnetite and ilmenite. Ore minerals show metamorphic equilibrium textures and the T of final equilibration of sulfides is 500°C or higher. Sulfide lodes have low but variable abundances of base metals. No correlation among total sulfide contents, sulfide minerals, and abundances of base metals and Au is observed. Nor is there any geochemical coherence between Au and arsenopyrite in the several lodes studied.

The vein-type mineralization has only trace amounts of sulfides with galena as the dominant phase (Narayanaswami et al., 1960). The veins consist dominantly of quartz with minor amounts of calcite and alkali feldspar and trace amounts of scheelite and tourmaline. The Au content of the veins is generally >10 ppm. These observations and the fluid inclusion studies on quartz (Santosh, 1986) suggest the presence of CO_2-bearing ore fluids. The geochemical data suggest that the Au quartz veins were formed dominantly from magmatic fluids derived from the crystallization of granitic rocks. A contribution from metamorphic fluids is also conceivable as indicated by the abundance of Ni and Cr in the veins. (From authors' abstract by E.R.)

SIMMONS, S.F., 1988, Utilisation of fluid inclusion studies in epithermal exploration: Examples from Mexico and Indonesia: Geol. Soc. New Zealand Miscellaneous Publication 41a, p. 134.

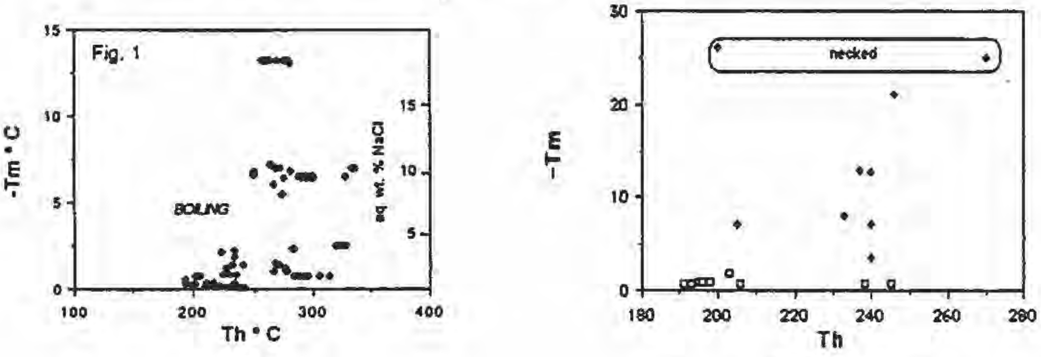
A review. (E.R.)

SIMMONS, S.F., 1989, Evolution of brines of magmatic(?) and meteoric origin in arc-related geothermal systems: Examples from the Fresnillo Ag-Pb-Zn district, Mexico, and Broadlands, New Zealand (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 243. Author at Geology Dept., Auckland Univ., Private Bag, Auckland, New Zealand.

Brine fluids occur in active and fossil magmatic-related geothermal systems of arc setting; they play a prominent role in the formation of epi- and meso-thermal Ag-Pb-Zn deposits whereas their presence in Au-Ag epithermal deposits, and analogous geothermal systems, appears ephemeral. Two contrasting evolutionary paths for brine fluids are exemplified in detailed FI studies of the Fresnillo district and the Broadlands geothermal system. Importantly, these systems formed in strikingly similar geologic and tectonic settings, during felsic magmatism.

At Fresnillo, evidence from early mineralization at the center of the district indicates the coexistence of two compositionally distinct fluids of (a) 10 eq. wt % NaCl and (b) <4 eq. wt % NaCl, which cooled from 300°C to <250°C, and boiled intermittently, while fluctuating from lithostatic to hydrostatic conditions (80 to 30 bars) at an estimated paleodepth of 325 m. A third more saline brine was also present. Late mineralizing fluids identified in epithermal veins from the periphery of the district also indicate the presence of two distinct fluids of essentially similar compositions at 180°-260°C; here brine fluids were injected into veins in cyclic pulses which specifically relate to periods of Ag-Pb-An sulfide deposition. Regionally, the water table appears to have lowered by as much as 400 m between these early and late mineralizing events. These data, plus absence of evidence for fluid mixing, imply density stratification between a deep brine reservoir and shallow, dilute meteoric fluids within an extremely dynamic geothermal system. Geologic, tectonic and isotopic evidence support a magmatic origin for brines; hence by inference, injection of brine pulses is thought to have been triggered by release of fluids during crystallization, or by recurring intrusion of magmas at depth. However, based on conceptual models of magmatic brine evolution (Fournier, 1985, USGS PP 1350), it is apparent that P-T paths of cooling magmatic vapors would generate a diversity of salinities in liquid condensates; such diversity has yet to be observed, and generation of the Fresnillo brines with relatively constant compositions remains ambiguous.

At Broadlands, brines identified in S inclusions (9 total) from a single sphalerite crystal (DH-16, 300 m depth) range from 1 to >20 eq. wt % NaCl, but differ significantly from present day fluid salinities of ~0.2 wt % NaCl and other inclusions within the same sample. Most brine hosted FI homogenize at ~240°C, and most likely originate from the continuous boiling of a single pulse of dilute meteoric fluid. This requires at least 99% vaporization of the parent liquid, which could be accomplished where cooler fluids encountered much hotter rock, resulting very locally in a fluid boiling to virtual dryness. Conversely, isothermal boiling to dryness may result from a P decrease where the T was buffered by a sufficiently large rock mass. (Author's abstract)



Fresnillo

Broadlands

SIMONEIT, B.R.T. and KAWKA, O.E., 1989, Generation temperature constraints on the aromatic composition of hydrothermal petroleums (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A48.

SINNINGHE DAMSTÉ, J.S., RIJPSTRA, W.I.C., DE LEEUW, J.W. and **SCHENCK, P.A.**, 1989, The occurrence and identification of series of organic sulphur compounds in oils and sediment extracts: II. Their presence in samples from hypersaline and non-hypersaline palaeoenvironments and possible application as source, palaeoenvironmental and maturity indicators: Geochim. Cosmochim. Acta, v. 53, p. 1323-1341.

SINNINGHE DAMSTÉ, J.S., RIJPSTRA, W.I.C., KOCK-VAN DALEN, A.C., DE LEEUW, J.W. and **SCHENCK, P.A.**, 1989, Quenching of labile functionalized lipids by inorganic sulphur species: Evidence for the formation of sedimentary organic sulphur compounds at the early stages of diagenesis: Geochim. Cosmochim. Acta, v. 53, p. 1343-1355.

SIRKKA, T.H. and **TARKIAN, M.**, 1989, Fluid inclusion studies in relation to mineralogy and ore paragenesis of the Kongsberg silver deposit, Norway (abst.): Terra Abstracts, v. 1, p. 35. Authors at Mineral.-Petrogr. Inst. der Univ., Hamburg, FRG.

On the basis of the results of FI studies, geochemical data and textural evidence fluid-mixing processes are concluded for the ore genesis, and its relation to magmatic events in context with the opening of the Oslo Graben is discussed. (From authors' abstract by E.R.)

SISSON, V.B., 1989, Fluid inclusions in hydrothermally altered synmetamorphic granitic rocks in south-central Maine (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 59. Author at Dept. Geol. and Geophys., Rice Univ., Houston, TX 77521-1892.

Hydrothermal activity during the waning stages of regional metamorphism in south-central Maine has altered synmetamorphic granitic stocks. This has resulted in variable alteration of biotite to chlorite and of feldspar to muscovite with calcite and/or epidote. Rumble et al. (1986) documented a consistent correlation between the mineralogy of altered rocks and the oxygen isotope composition of whole rocks, quartz, and feldspar. Furthermore, they found that mineralogic and isotopic alteration is coupled with the equilibrium fluid composition calculated for the hydrothermal alteration at 400-450°C at a depth eq. of 10 to 13 km. Ferry (1978) has predicted that samples with muscovite and calcite have CO_2-H_2O fluids with $XCO_2 = 0.03$ to 0.13 whereas those with muscovite and variable proportions of both calcite and epidote had $XCO_2 \leq 0.03$.

Comparison of FI compositions with the oxygen isotope data and mineralogic assemblages demonstrates that all three techniques suggest similar equilibrium fluid compositions. The composition of early fluids observed in quartz, garnet and feldspar differs between samples with different S minerals. Samples with muscovite and calcite which are predicted to have an average fluid composition with $XCO_2 = 0.05$ are observed to have rare P FI with $XCO_2 = 0.10$. Those with muscovite + calcite + epidote have FI with brines with a low to moderate salinity and a minor CO_2 component documented by the presence of clathrate melting at +8 to 10°C. These samples are predicted to coexist with fluids of $XCO_2 = 0.02$-0.03. Finally, rocks with muscovite ± epidote have only inclusions with low to moderate salinity brines and are predicted to have $XCO_2 < 0.02$. The correlation between the predicted and observed fluid compositions suggests that these FI were trapped during the hydrothermal alteration.

Several samples also have S water-rich FI. This population of FI typically is inhomogeneous with variable vapor to liquid ratios along single cross-cutting fractures. The S inclusions often occur along grain boundaries suggesting late infiltration of water after the hydrothermal activity. S FI in the adjacent metamorphic rocks are also low salinity brines. These have densities similar to the early low salinity brines observed in the hydrothermally altered granite. Thus, similar fluids are inferred to have infiltrated both the plutons and associated country rock during the hydrothermal activity following peak metamorphism. (Author's abstract)

See also Sisson et al., Fluid Inclusion Research, v. 20, p. 358-359. (E.R.)

SKALICKY, Josef and **DURISOVA, Jana**, 1989, Quartz crystals from the environs of Thon Vinh Truong (Vietnam); Vestnik Ustredniho ústavu geologického, v. 64, no. 6, p. 369-371.

Quartz crystals of unknown origin were found in eluvia of the Deo Ca granitoid body (Vietnam) during geological mapping. Investigation of FI by microthermometry methods has revealed that the quartz crystals crystallized from hydrothermal solutions of low salinity (3.5-7 wt % NaCl eq.) at ~400°C. At certain stages of the hydrothermal process the solutions contained CO_2 with admixed methane. With respect to their physical properties, the quartz crystals are suitable for jewelery purposes. Their use in electrotechnics is not recommended. (Authors' abstract)

SKIRIUS, C.M., 1989, Pre-eruptive H_2O and CO_2 in plinian and early ash-flow magma of the Bishop Tuff (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 245. Author at Dept. Geophysical Sciences, Univ. Chicago, Chicago, IL 60637.

Glass inclusions in quartz phenocrysts from individual lumps of pumice collected from stratigraphic levels within the plinian air fall deposit and three overlying early ash-flow units of the Bishop Tuff were analyzed by Fourier transform infrared (FT-IR) spectroscopy for their H_2O and CO_2 contents. Most of the plinian inclusions (70%) yielded 5-6 wt % H_2O and $\leq$0.01 wt % CO_2. Inclusions from lumps of pumice from the same plinian stratigraphic levels have comparable ranges in H_2O and CO_2. Ash-flow inclusions yielded approximately the same range in H_2O concentrations with ~50% of the inclusions having higher (0.01-0.02 wt %) CO_2 concentrations. Anderson et al. (in press) reported lower H_2O (~4.3 wt %) and higher CO_2 (up to 0.066 wt %) for inclusions analyzed by FT-IR from the latest and hottest Mono Lobe ash flow. Assuming that the magma was gas-saturated prior to eruption as put forth by Anderson et al., then the plinian and ash-flow crystals grew at H_2O-CO_2 saturated P of ~1500 to 2400 bars, in accord with their findings. A few plinian inclusions have up to 7 wt % H_2O and 0.024 wt % CO_2 and evidently formed at greater depth.

A group of devitrified plinian and ash-flow inclusions were heated in an internally-heated gas pressure vessel at 800°C and 2 kbar for ~20 hrs and quenched at P prior to spectroscopic analysis. This procedure dissolved the devitrification products (crystals ± vapor bubbles) and produced clear, glassy, unfractured samples which yielded 5.0 to 5.8 wt % H_2O and $\leq$0.02 wt % CO_2, values similar to the majority of unheated inclusions, and allows the initial volatile content of previously unsuitable devitrified samples to be determined. The overlap in H_2O and CO_2 concentrations between plinian and early ash-flow inclusions suggests that both plinian and early ash-flow material sampled similar depths within the pre-eruptive magma body. (Author's abstract)

SKIRIUS, C.M., PETERSON, J.W. and ANDERSON, A.T., Jr., 1989, Pre-eruptive volatile content of Bishop Tuff ash flow magma: Results of glass inclusion homogenization experiments (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A270. Authors at Dept. Geophysical Sciences, Univ. Chicago, Chicago, IL 60637.

Devitrified inclusions (crystals + gas bubbles) in quartz phenocrysts from ash flow emplacement units of the Bishop Tuff were homogenized by heating prior to infrared (FT-IR) spectroscopic measurement of H_2O and CO_2. Crystals with documented inclusions were encapsulated in loosely crimped Pt tube segments and heated in an internally-heated Ar pressure vessel to 800°C or 900°C at 2 kbar for ~20 hours. Samples were quenched nearly isobarically (~5°C/sec. quench rate). This procedure yielded glassy, unfractured inclusions free of crystals and gas bubbles. Inclusions that were cracked prior to heating do not revitrify possibly due to loss of volatiles during post-eruptive cooling. Cracks develop around homogenized inclusions during polishing due to stress caused by the 1 vol % shrinkage of quartz at the β-α transition. No significant difference exists between heated and unheated inclusions for any of seven major elements and Cl.

Concentrations of H_2O and CO_2 in homogenized inclusions span similar ranges to those measured in unheated inclusions from stratigraphically equivalent samples. The values of H_2O and CO_2 measured for homogenized inclusions are thus taken to represent the restored P trapped melt compositions. In particular, homogenized inclusions from the high-T Mono Basin Lobe range from 4.0-4.6 wt % H_2O and 0.02-0.06 wt % CO_2 compared to 4.3 wt % H_2O and ~0.06 wt % CO_2 in unheated (natural) slightly devitrified, bubble-bearing inclusions from the same sample (Anderson et al., 1989, Geology, 17, 221-225). The CO_2 results of Anderson et al. are based on reconstruction of bulk inclusion composition by adding back into the melt an amount of CO_2-rich gas calculated to be in the bubbles. Some homogenized Mono Basin Lobe inclusions contain 0.018-0.025 wt % CO_2 similar to early ash flow and Plinian inclusions. This suggests that the Mono Basin Lobe tapped similar depths as the lower-T magma if gas-saturation is assumed. However, the distinct small size, negative-crystal shape, lower H_2O and higher K_2O of the Mono Basin inclusions may indicate that the Mono Basin ash flow represents a different or more isolated body of magma extending throughout the same depth-range as the other ash flows and Plinian magma. (Authors' abstract)

SKOGBY, Henrick [sic], **BELL, D.R.** and **ROSSMAN, G.R.**, 1989, Hydroxide in pyroxenes (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A241.

SKOGBY, Henrik [sic] and **ROSSMAN, G.R.**, 1989, OH- in pyroxene: An experimental study of incorporation mechanisms and stability: Am. Mineral., v. 74, p. 1059-1069.

SLACK, J.F., **PALMER, M.R.** and **STEVENS, B.P.J.**, 1989, Boron isotope evidence for the involvement of non-marine evaporites in the origin of the Broken Hill ore deposits: Nature, v. 342, p. 913-916. First author at U.S. Geol. Survey, National Center, MS 954, Reston, VA 22092.

Identifying the palaeogeographic setting and mode of origin of stratabound ore deposits can be difficult in high-grade metamorphic terranes, where the effects of metamorphism may obscure the nature of the protoliths. Here we report boron isotope data for tourmalines from the early Proterozoic Broken Hill block, in Australia, which hosts giant lead-zinc-silver sulphide deposits. With one exception the $^{11}B/^{10}B$ ratios are lower than those for all other tourmalines from massive sulphide deposits and tourmalines elsewhere in the world. We propose that these low ratios reflect leaching of boron from non-marine evaporitic borates by convecting hydrothermal fluids associated with early Proterozoic continental rifting. A possible modern analogue is the Salton Sea geothermal field in California. (Authors' abstract)

SMITH, J.T. and **EHRENBEG, S.N.**, 1989, Correlation of carbon dioxide abundance with temperature in clastic hydrocarbon reservoirs: Relationship to inorganic chemical equilibrium: Marine and Petrol. Geol., v. 6, p. 129-135. First author at Shell Oil Co., PO Box 481, Houston, TX 77001, USA.

The mol % CO_2 of gas reservoired in sandstones tends to increase with increasing T along both the US Gulf Coast and the Norwegian continental shelf. We suggest that the log $P(CO_2)$ *versus* T correlation is the result of inorganic chemical equilibria between feldspar, clay, and carbonate minerals. This model predicts that CO_2 released by organic maturation will, in general, result in precipitation of carbonate minerals below 100-120°C and that there should be widespread carbonate dissolution at higher T. (From authors' abstract by E.R.)

SMITH, J.V., **RIVERS, M.L.**, **SUTTON, S.R.** and **JONES, K.W.**, 1989, Synchrotron X-ray fluorescence analysis; current experiments and future prospects (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A172.

SMITH, P.K. and **KONTAK, D.J.**, 1989, Caribou gold deposit, Nova Scotia: Composite ore zone geometry and restrictions on the age of mineralization (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-2. Authors at Nova Scotia Dept. Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1, Canada.

The Caribou Au deposit represents the first documentation of contrasting styles of mineralization in a turbidite-hosted Au deposit of the Lower Paleozoic Meguma Group. Chlorite-grade, greywacke-dominated strata are folded into the E-trending (070°) Caribou Dome which hosts numerous auriferous and barren quartz veins. Vein types include bedding parallel (bp) (± ribbon texture), angular, en echelon, ac, bull-crosscutting, and stockwork. Vein mineralogy is dominated by quartz-carbonate-chlorite with low sulphide content. All vein types host Au, although historical production (~91,500 oz.) was mainly from bp and stockwork types. A major SE-trending (135°) flexure (No:1 Flexure) deforms all earlier structures and dips moderately westward. High-grade vein mineralization is restricted to intensely altered (silica, carbonate, sulphide) greywacke intersected by this flexure. Although four auriferous stockwork zones on the No:1 Flexure are currently being explored, the entire axial plane of the No:1 Flexure hosts auriferous stockwork. Plunging ore shoots in the stockwork quartz parallel the intersection of bedding with the No:1 Flexure (~40° SW). However, ore shoots within bp veins plunge both east and west, parallel to intersections with other vein types, shear lineations and/or the stockwork system. Although the age of ribbon veins remains contentious, Au associated with the flexure provides maximum age restrictions (i.e., post regional deformation). Thermometric data for FI (H_2O-CO_2-CH_4-NaCl) from all vein types are similar, therefore suggesting a close temporal association. (Authors' abstract)

SO, C.-S., YUN, S.-T., CHOI, S.-H. and SHELTON, K.L., 1989, Geochemical studies of hydrothermal gold-silver deposits, Republic of Korea: Youngdong mining district: Mining Geol., v. 39, no. 1, p. 9-19. First author at Dept. Geol., Korea Univ., Seoul 136, Republic of Korea.

Electrum-sulfide mineralization of the Daeil and Yeongbogari mines in the Youngdong area consists of two stages of quartz and calcite veins that fill fault zones in Precambrian metamorphic rocks. Radiometric dating indicates that mineralization of the Daeil mine is Jurassic age (145 Ma), whereas that of the Yeongbogari mine is Cretaceous (132 Ma). Mineralogy of the two mines differs significantly in that only the Yeongbogari mine contains Ag-bearing minerals (argentite, argentian tetrahedrite, pyrargyite) and its electrums are more Ag-rich (49.1 to 71.4 wt % Ag) than those of the Daeil mine (28.0 to 37.8 wt % Ag).

FI data show that ore mineralization occurred at between 375° and 246°C from fluids with salinities between 9.1 and 2.6 wt % eq. NaCl. The estimated T and S fugacity for Au deposition in the Jurassic Daeil mine are much higher (≈350°C, 10^{-9} atm.) than those for the Cretaceous Yeongbogari mine (≈275°C, 10^{-12} atm.). FI evidence of boiling indicates P of <200 bars, corresponding to depths of 800 to 2,600 m assuming lithostatic and hydrostatic P regimes, respectively.

S isotope compositions of sulfide minerals are consistent with S from igneous sources in the Daeil and Yeongbogari mines. Estimated $\delta^{34}S(\Sigma S)$ values for the Daeil and Yeongbogari mines are 8 and 3‰, respectively, which may reflect differences in the separation of S-bearing magmatic fluids from their associated granitic magmas.

The difference in ages, mineralogy and ore deposition conditions between the Jurassic Daeil and Cretaceous Yeongbogari deposits further validates the idea of multiple Au-Ag metallogenic epochs in Korea. Deposits associated with Jurassic granites are formed at typically deeper and higher T conditions and are more Au-rich than those associated with Cretaceous granites. (Authors' abstract)

SOBOLEV, A.V. and DMITRIEV, L.V., 1989, Primary melts of tholeiites of oceanic rifts (TOR): Evidence from studies of primitive glasses and melt inclusions in minerals (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-147-148. Authors at Vernadsky Inst. Geochemistry, Moscow, U.S.S.R.

The knowledge of the composition and PT conditions of formation of primary melts (PM) of TOR is a key to understanding the origin of global geochemical reservoir within mantle that produce the majority of Phanerozoic basaltic magmas.

In the present paper, we attempt to estimate the compositions and PT conditions of formation of PMs for major types of TOR. To do this, we use detailed mineralogical studies, investigation of melt inclusions in minerals, and numerical modeling of crystallization of primitive glasses. As criteria of primarity, any PM should be in equilibrium with its mantle source (restite).

Melt inclusions in the most magnesian olivines: Melt inclusions were investigated by Th in optical high-T cell. Compositions were determined by electron microprobe (Table 1). (From authors' abstract by E.R.)

Table 1. The composition of melt inclusions in most magnesian olivines (1-4) and representative calculated primary melts (5-7).

NN Type	1 TOL ???	2 TOR 1	3 TOR 2	4 TOR 3	5 PM TI	6 PM TOR 1	7 PM TOR 2
SiO_2	48.80	49.00	50.14	52.80	48.40	48.93	49.60
TiO_2	.50	.60	.87	.30	.50	.56	.90
Al_2O_3	14.10	15.00	17.94	15.80	14.10	15.65	18.60
FeO	7.81	7.60	7.11	7.00	8.21	7.68	7.20
MgO	14.00	13.00	9.60	9.60	14.50	13.87	9.40
CaO	13.20	12.30	12.57	13.00	12.70	11.76	12.00
Na_2O	1.40	1.60	2.34	1.40	1.40	1.48	2.30
K_2O	.02	.06	.06	.03	.02	.01	.04
Total	99.83	99.16	100.63	99.93	99.83	99.94	100.04
Mg#	.762	.753	.707	.710	.759	.763	.699
Host	Fo 92.0	Fo 91.5	Fo 90.1	Fo 90.0	Fo 92.2	Fo 92.0	Fo 90.5
Th	1325	1290	1240	1220	1336	1324	1230

SOBOLEV, A.V., GURENKO, A.A. and SOBOLEV, N.V., 1989, Petrology of ultrabasic ultrapotassic magmas of continental lithosphere: Results of inclusions studies in olivine from lamproites, kimberlites, and kamafugites (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-146-147. First author at Vernadsky Inst. Geochemistry, Moscow, U.S.S.R.

The problem was to determine composition and crystallization condition (T, P, fO_2) of early liquidus assemblages, composition of fluid, and melt of K-rich ultrabasic magmas of the continental lithosphere (lamproites, kamafugites, kimberlites). On the basis of the information, an estimation of possible conditions of genesis and composition of a source of these magmas were made.

Lamproites have been studied on an example of the Kimberley Craton, West Australia (olivine lamproites of the pipes Ellendale 11.9; leucite lamproites of Mt. Cedric). Kimberlites from the Udachnaya-East pipe, Yakutia, have been studied. The kamafucites investigated were taken from the West African rift zone (ugandite and jafurite were sampled from lava flows of the craters Kazimiro and Kjambogo, respectively, West Uganda). All the rocks investigated are olivine-porphyric and typical of the most magnesian and less altered varieties of corresponding types.

Primary melt inclusions of lamproites, ugandite, and mafurite are present in the olivine. The estimation of early crystallization T has been done on the basis of two-pyroxene thermometer (Lindsley, 1983), olivine-spinel thermometer (Fabrier, 1979), ilmenite-magnetite thermometer (Spencer and Lindsley, 1981) as well as by the method of melt inclusion Th (Roedder, 1984). The following estimates have been obtained for most magnesian olivines: 1200-1060°C for olivine and leucite lamproites, 1300-1100°C for kimberlites, 1200-1150°C for ugandite and mafurite. A subsequent melt fractionation occurred up to 1000-950°C for lamproites and ugandites and 850°C for mafurites.

P fluid inclusions have been found in magnesian olivines of all rocks investigated, which evidence the saturation of melts by a fluid component at an early stage of crystallization. According to Raman spectroscopy data, the fluid composition corresponds to CO_2, with trace of CO and N_2 up to 2-3 mol %. The H_2O content in the fluid is less than 1-2 mol % for ugandites and mafurites, and less than 10 mol % for lamproites and kimberlites. The maximum fluid P at the crystallization stage is estimated to be of 4-5 kbar for all rocks investigated.

The melt compositions are determined at the stage of the second-generation olivine crystallization of lamproites, ugandite, and mafurite. The melts are characterized by extremely high content of alkalies, especially of K, high contents of Ti, P, Ba, Sr, and F, and low contents of al and Ca.

The studied K-rich melts are characterized by lowest T of crystallization among mantle originated magmas and can be due to melting of lithosphere without considerable overheating in relation to the geotherm of stable regions and thus without active mantle diapirism. The most probable cause of the origin of K-rich ultrabasic melts is metasomatism of predepleted harzburgitic material of the lithosphere realized by fluid (melt) of high CO_2/H_2O ratio. Differences in composition of the studied ultrabasic K-rich magmas are due to a different extent of the source predepletion and different conditions of melting. The least depleted and most high T source is characteristic for kimberlite, the most depleted and least high T source for lamproites with kamafugites somewhere between. The extent of incompatible elements enrichment as well as their isotopy is controlled by composition and origin of metasomatic component. (From authors' abstract by E.R.)

Includes four analyses of melt inclusions in olivines. (E.R.)

SOBOLEV, A.V., KAMENETSKY, V.S. and KONONKOVA, N.N., 1989, New data on petrology and geochemistry of ultramafic volcanics of the Valaginsky Range, eastern Kamchatka: Geokhimiya, no. 12, p. 1694-1709 (in Russian). First author at Vernadsky Inst. of Geochem., 117975 Moscow, Kosigin str. 19, U.S.S.R.

Ultramafic volcanics of the Valaginsky Range, eastern Kamchatka, form pillow-lavas and dikes within a late Cretaceous volcanic belt. Picrites associate often in cross sections with clinopyroxene-porphyric basalts and tuffs. Picrites display the widest compositional range in MgO content (from more than 40 to 15 wt %) and contents of other components, controlled by the amount and composition of olivine.

Olivine phenocrysts are exceptionally magnesian, ranging from unusually high Fo 94.5 down to Fo 89. Spinel is found as inclusions in olivine and is characterized by high chromium (Cr #80-60 mol %), low titanium ($TiO_2 < 0.8$ wt %) and low Fe^{2+}/Fe^{3+} ratio < 1), showing evidence for high oxygen fugacity during crystallization. Clinopyroxene phenocrysts are minor; they are Ca-rich and Ti-poor, often zoned and have range in $Mg/Mg+Fe^{2+}$ from 92 to 70 mol %. Some part of olivine crystals include combined inclusions of magnesian clinoenstatite and acid glass. This is the second finding (after boninites) of clinoenstatite in terrestrial rocks.

Melt and fluid inclusions in olivine and clinopyroxene were investigated to determine conditions of crystallization. Based on optical high-T thermometry and compositional studies of quenched melt inclusions, it has been found that ultramafic volcanics were formed as a result of near-surface crystallization of ultramafic melt in the T range 1500 to 1030°C. The calculated composition of the P melt corresponds to komatiite with exceptionally high contents of alkalies and phosphorus and high K_2O/Na_2O ratios ($K_2O/Na_2O > 1$). It is concluded that the P melt evolved by crystal fractionation with formation of absarokite-shoshonite series of island-arc type. Data obtained suggest the formation of the P melt as a result of mantle lherzolite partial melting at 130-170 km depth and 1600-1700°C. This is the new evidence for occurrence of exceptionally high T in mantle source regions in Phanerozoic time. (Abstract by T. Sushchevskaya)

SOBOLEV, A.V., SOBOLEV, N.V., SMITH, C.B. and **DUBESSY, Jean**, 1989, Fluid and melt compositions in lamproites and kimberlites based on the study of inclusions in olivine, *in* J. Ross et al., eds., Kimberlites and Related Rocks, Vol. 1, Their composition, occurrence, origin and emplacement: 4th Int'l Kimberlite Conference, Perth 1986, Geol. Soc. Australia Spec. Publ. No. 14, pp. 220-240. First author at Vernadsky Inst. Geochemistry, Academy of Sciences USSR, Moscow, U.S.S.R.

Full paper for abstract in Fluid Inclusion Research, v. 19, p. 412, 1986. (E.R.)

SOLOVOVA, I.P., GHIRNIS, A.V., KOGARKO, L.N., RYABCHIKOV, I.D., NAUMOV, V.B. and **GUZHOVA, A.V.**, 1989, Geochemical peculiarities of Prior Creek lamproites based on data of study of microinclusions in olivines: Geokhimiya 1989, no. 10, p. 1449-1459 (in Russian, English abstract).

The melt and fluid microinclusions in olivines of Prior Creek lamproites (Arkansas, USA) have been studied at P of 1 bar to 7 kbar and T of -190° to 1300°C. Using microprobe the compositions of residual and homogenized glasses, dms in the inclusions and crystalline phases in olivines have been investigated. It has been found that magmas formed the intrusive rocks under study were of high agpaicity with contents of K_2O up to 15 wt % and P_2O_5 up to 4.5 wt %. Crystallization of the melt occurred at conditions of undersaturation of volatiles (H_2O and CO_2) with predominance of CO_2 over H_2O. High-Cr spinel and olivine with Mg = 0.89 to 0.92 are the liquidus phases. Crystallization began at 1000 to 1050°C and >4 kbar. (Authors' abstract)

SONG, Huanbin, 1989, Ore-forming characteristics of the Dulong cassiterite-sulfide type ore deposit in southeastern Yunnan: Mineral Deposits, v. 8, no. 4, p. 29-38 (in Chinese, English abstract). Author at Dept. Geology, Kunming Inst. Technology, Kunming, Yunnan.

The Dulong Sn deposit is the largest Sn, W polymetallic deposit in Laojunshan, southeastern Yunnan and is also one of the three large Sn bases in China. The deposit is of cassiterite-sulfide polymetallic type which occurs within Cambrian strata in contact with the Laojunshan granite intrusion. In addition to the main element Sn, it contains such associated recoverable elements as Zn, Ag, Cu and Fe. The main ore types include cassiterite-sulfides, cassiterite-silicates and cassiterite-magnetite, with the cassiterite disseminated in micrograined form (generally <74 µm) in the ore.

Based on researches on sources of ore-forming elements, ore-controlling factors and physical-chemical conditions for metallogenesis, the author holds that Sn was derived from Laojunshan granite instead of from the strata, that the migration and deposition of metallogenic elements were controlled by faults, fissures and lithological characteristics of the wall rocks and that the ore deposit was formed in a physical-chemical environment where ore-forming fluids had high T (3000-400°C [sic]), low salinity (5.5 NaCl wt %) and density (0.9-1.0 $g{\cdot}cm^3$) and high in volatiles such as F, thus belonging to the deuteric hypothermal type.

The Laojunshan granite, being a crustal anatectic granite intruded in Yanshanian Period with isotopic age 89-118 Ma, contained abundant Sn (even reaching 70 ppm) and thus served as the ore-forming parent rock providing excellent background for metallogenesis. (Author's abstract)

SONYUSHKIN, V.Ye. and **PETROVA, T.L.**, 1988, Use of complex electron microscope methods for study of morphology and bulk composition of fluid inclusions in quartz (a review), *in* V.A. Kalyuzhnyi et al. (eds.), Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press, p. 10-20 (in Russian).

Transmission electron microscope (model EM-802) studies were made with standard methods of replicas, suspensions and microdiffraction; for the scanning electron microscope studies, the device ISI-60 with energy dispersive analyzer [EDA] LINK-860 was applied. The energy dispersive method results were compared with the results obtained on the wavelength dispersive microprobe [WDA] Microscan-5. The preparations were made as follows: (1) selection of quartz zones with abundant inclusions up to 5 μm in size by light microscopy; (2) inclusion opening by chipping of the selected quartz pieces along the {1011}, {0111} and {1010} cleavage planes; (3) leaching of one of the cleavage surfaces by hot distilled water, preparation of a suspension from the obtained solution, and suspension studies by TEM (microdiffraction) and SEM (microanalysis), (4) carbon coating of the other cleavage surface and microanalysis of the mineral and precipitated salts in the inclusion vacuole; (5) studies of the separation carbon replica by TEM, microdiffraction of particles adhering to the carbon replica; and (7) coating of the washed cleavage surface by carbon and studies of the vacuole morphology by TEM and SEM. For melt inclusion studies the preparations were ground and polished. Sometimes the cleavage surface was cleaned (washed) using an ultrasonic bath. In the vacuole morphology the "replicas" of the daughter and/or trapped minerals or the gas bubbles occurred, as well as growth figures and etch pits. The layer of substance precipitated from the inclusion volume on the inclusion vacuole walls had especially distinct growth features.

Melt inclusion compositions were studied by means of the electron microprobe in quartz from the Samshvildo porphyry (Caucasus). Melt inclusions in this porphyry were overheated after sealing, resulting in their decrepitation, formation of unusually large gas bubbles and halos of daughter inclusions. Differences in element contents (Na, Al, Si, K, Ca, Fe) in glass were found between the centers and the margins of the melt inclusions. The listed elements concentrated also on the surface of the gas bubble. These differences are explained by the overheating process. The WDA method was found to be more suitable for melt inclusion analysis due to higher resolution than the EDA method and the lower detection limits of some ore elements, e.g., there were found in melt inclusions: Ni 0.01-1.25, Co 0.02, Cu 0.002, Au 0.008 (in wt %).

Mineral particles in inclusions can be best identified after their extraction by use of the carbon replicas. This way, also xenogenic trapped crystals (e.g., graphite) were identified.

Inclusion solution precipitate composition (NaCl and KCl mostly) were calculated on the basis of the planimetry of the scanning images. Measurements for standard solutions of NaCl and KCl gave an accuracy of 2-3%. When solutions dried rapidly to form a fine-grained precipitate, the EDA determinations gave for the NaCl and KCl contents an accuracy of 0.5% [i.e., ±0.5%?—A.K.]. Also EDA analysis of the deeply frozen inclusions has been made. (A.K.)

SONYUSHKIN, V.E. and **ROSEN, O.M.,** 1989, Microstructure of quartz and flow stress in polymetamorphic rocks of Anabar shield: The Archean folding flow and the Proterozoic interplate sliding (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-154. Authors at Academy of Sciences of the USSR, Moscow, U.S.S.R.

Data of petrology and fluid inclusions shows the metamorphic parameters for the Anabar complex to be $P = 7.5\text{-}11$ kbar, $T = 800\text{-}1000$°C, for the Lamujka complex $P = 6\text{-}7.5$ kbar, $T = 750\text{-}850$°C, and for the last tectonites these parameters lower down to $P = 0.7$ kbar, $T = 200\text{-}300$°C. (From authors' abstract by E.R.)

SOUTHGATE, P.N., LAMBERT, I.B., DONNELLY, T.H., HENRY, R., ETMINAN, H. and **WESTE, G.,** 1989, Depositional environments and diagenesis in Lake Parakeelya; a Cambrian alkaline playa from the Officer Basin, South Australia: Sedimentology, v. 36(6), p. 1091-1112.

Indexed under FI. (E.R.)

SPECZIK, S. and **EL-SAYED, A.A.Y.,** 1989, Origin of barite occurrences in the Bahariya Oasis, western desert, Egypt (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 86. First author at Dept. Geol., Univ. Warsaw, Warsaw, Poland.

The Bahariya Oasis is situated about 370 km southwest of Cairo. The barite occurrences which are associated with the Fe-ore deposits of El-Gedida, El-Harra and Ghorabi, lie within the northern part of the Bahariya depression, about 20 km northeast of El-Bawiti village.

Barite occurs as disseminated grains, cement and fracture filling in the Upper Cenomanian Bahariya Formation El-Harra. Reworked fragments of the barite mineralization occur along the unconformity surface between the Bahariya Formation and the Middle Eocene Nagb Formation that host the Fe ores at El-Gedida and Ghorabi. Previous work has shown that there are two generations of barite, one earlier and the other later than the Fe mineralization. The latter has been interpreted as a result of deposition from rising hydrothermal solutions released from nearby Tertiary volcanic rocks.

Barite contains abundant liquid inclusions and rarer gas-liquid inclusions. In some samples, gas-liquid inclusions are very common; this tends to support the idea of an hydrothermal origin for the barite. However, detailed studies of all forms and modes of barite do not confirm this interpretation. Three generations of inclusions have been recognized. Two generations relate to barite crystallization and its progressive coalescence and recrystallization (predominantly liquid inclusions). The third is related to the infiltration of rising solutions of meteoritic origin (often gas-liquid inclusions). Possible mechanisms that led to the development of gas-liquid inclusions will be discussed. The Bahariya Oasis barites associated with Fe ores are considered to be of infiltration meteoric water origin. (Authors' abstract)

SPENCER, J.E., GRUBENSKY, M.J., DUNCAN, J.T., SHENK, J.D., YARNOLD, J.C. and **LOMBARD, J.P.,** 1989, Geology and mineral deposits of the central Artillery Mountains, *in* J.E. Spencer and S.J. Reynolds (eds.), Geology and Mineral Resources of the Buckskin and Rawhide Mountains, West-central Arizona: Arizona Geol. Surv. Bull. 198, p. 168-183. First author at Arizona Geol. Surv., 845 N. Park Av., #100, Tucson, AZ 85719.

The Artillery Mountains contain the largest known Mn reserves in the United States. Most of the Mn deposits are sedimentary in origin and are hosted by the Chapin Wash Formation. Fracture-filling Mn deposits at the Shannon and Priceless mines are younger than the Chapin Wash Formation. Quartz, calcite, and barite gangue minerals within these two Mn deposits contain fluid inclusions having less than 3 wt % NaCl eq. Fluids in these inclusions are significantly less saline than those in nearby detachment-fault-related Cu-Fe deposits, which indicates that the two deposit types are not closely related. (From authors' abstract by E.R.)

SPENCER, J.E., REYNOLDS, S.J., GRUBENSKY, M.J., DUNCAN, J.T. and **WHITE, D.C.,** 1989, Geology of the Vulture gold mine: Arizona Geol., v. 19(4), p. 1-3.

Indexed under FI. (E.R.)

SPENCER, R.J., 1989, Composition of brines in fluid inclusions: A low temperature thermochemical model for the system Na-K-Ca-Mg-Cl-SO_4-H_2O (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 60. Author at Dept. Geol. and Geophys., The Univ. Calgary, Calgary, Alberta, T2N 1N4, Canada.

Brine-filled FI are common in many sedimentary minerals. P FI in diagenetic minerals such as calcite, dolomite, anhydrite, fluorite and quartz as well as P FI from syndepositional halite are small; most are less than 10 µm across. Determination of the composition of brines in these small P FI constrains the origin of depositional and diagenetic phases. Among the topics of interest are the origin of dolomite and the marine or non-marine nature of evaporite parent waters. It is possible to obtain information on the composition of even small (2 to 4 µm) FI from observations of the melting (or dissolution) T of solid phases. Required for the analysis are the identification of the solid phases, determination of the melting points and a thermochemical model covering the range of T and brine compositions. A thermochemical model for the system Na-K-Ca-Mg-Cl-SO_4-H_2O, from -60 to ~100°C is presented here.

Aqueous species are modelled using binary and ternary specific ion interaction terms. Each term varies independently with T. The T dependence of specific ion interaction parameters and standard chemical potentials for solid phase-solution reactions are each fit to an equation of the form:

$$P = a_1 + a_2T + a_3T_2 + a_4T_3 + a_5/T + a_6\ln T$$

The standard chemical potential for the water-ice reaction is determined from published data (vapor P and free energy) which extends 0° to -46°C, and is independent of the model. Specific ion interaction parameters and remaining standard chemical potentials of reactions are fit simultaneously at variable T. Published determinations of the melting points of ice and mineral solubilities from both binary and ternary systems are used to create the model. Model predictions are tested by comparison with experimental results of minerals formed and the composition of brines derived from chilling seawater to the eutectic.

The model may be used to calculate FI brine compositions based on melting points of solids. The completeness of the analysis is dependent on the number of solid phase melting T observed. The melting point of ice is sufficient to determine the activity of H_2O in solution; however, a wide variety of chemical compositions can produce a given activity of H_2O. A complete major element analysis for the Na-K-Ca-Mg-Cl-SO_4-H_2O system requires six constraints. Charge balance among the aqueous species is one constraint. Additional constraints are placed on the composition of brines by the melting points of solid phases in FI, the solubility of the host mineral and the solubilities of solids which are demonstrated petrographically to coprecipitate with the host. Each independent determination constrains a solution species concentration, ratio or product. (Author's abstract)

SPRINGER, Gunter, 1989, Chlorine-bearing and other uncommon minerals in the Strathcona deep copper zone, Sudbury district, Ontario: Canadian Mineral., v. 27, p. 311-313. Author at Falconbridge Ltd., Falconbridge, Ontario P0M 1S0, Canada.

A zone of Cu-rich ore in the footwall of the Strathcona orebody in the Sudbury district, Ontario, contains a number of uncommon minerals. These include froodite, moncheite and niggliite as carriers of Pt and Pd, and Fe hydroxy-chlorides that occur as fracture fillings and as inclusions in sulfide. Cl-bearing silicates also were found. Some of the silicates are rich in Mn. (Author's abstract)

SPRY, P.G. and **McGOWAN, K.I.,** 1989, Origin of Archean lode gold mineralization at Atlantic City-South Pass, Wyoming: Fluid inclusion and stable isotope study (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-163-164. Authors at Iowa State Univ., Ames, IA.

Considerable controversy exists in the literature concerning the source of hydrothermal fluids and ore components involved in the formation of Archean lode gold deposits. Geological, fluid inclusion, and stable isotope studies of Canadian and Australian Archean lode gold deposits have indicated several possible sources of fluid. A fluid inclusion and stable isotope study was undertaken on Au-quartz veins at Atlantic City-South Pass, Wyoming.

An intriguing part of the stable isotope study is the O and H isotope data ($\delta^{18}O$ = -10.7 to 3.5‰ and δD = -125 to -55‰) obtained from fluid inclusions in lode quartz. These data suggest either an evolved seawater or connate water brine of alternately mixing of meteoric water with a magmatic and/or metamorphic component. Compositions of the fluid inclusions, however, make the latter possibility seem less likely.

Four types of P and PS fluid inclusions have been observed: (1) three- and four-phase H_2O-CO_2-NaCl-$CaCl_2$ inclusions; (2) two-phase CO_2-CH_4 inclusions; and (3) one-phase CH_4 or CO_2 gaseous inclusions. Two types of S inclusions were also observed: (1) two-phase liquid-vapor aqueous inclusions; and (2) three-phase solid-liquid-vapor aqueous inclusions in which the solid phase is NaCl. Th for P inclusions range from 220° to 420°C whereas those for S inclusions range from 52° to 301°C. Due to the coexistence of H_2O- and CO_2-rich inclusions and CO_2-H_2O-bearing inclusions with variable CO_2:H_2O ratios, phase separation probably occurred. A salinity of 4 to 10 eq. wt % NaCl was obtained on P inclusions using Tm clathrate. S inclusions are more saline than P and PS inclusions, but each type has a significant $CaCl_2$ component. Te exhibits a range from -55° to -44°C. The high $CaCl_2$ content is rare for an Archean gold lode deposit.

The most plausible model for the formation of Au mineralization at Atlantic City-South pass is for fluids to have been derived by lateral secretion from greywackes in the Miners Delight Formation during compaction. O and H isotopes are typical of those associated with a basinal brine. Interaction of the ore-forming fluids with graphitic schists is indicated by the light values of $d^{13}C$ in gold-associated carbonates and by the presence of CH_4 in many fluid inclusions. The high $CaCl_2$ content of fluid inclusions may have formed by the release of Ca to the fluid during conversion of plagioclase in greywacke to K-feldspar. The source of the Au is equivocal; however, it is significant to note that iron formation and graphitic schist contain up to 120 to 49 ppb Au, respectively. (From authors' abstract by E.R.)

SPYCHER, N.F. and **REED, M.H.**, 1989, Evolution of a Broadlands-type epithermal ore fluid along alternative P-T paths: Implications for the transport and deposition of base, precious, and volatile metals: Econ. Geol., v. 84, p. 328-359. First author at Int'l Tech. Corp., 17461 Derian Ave., Suite 190, Irvine, CA 92714.

Boiling and acidification of hydrothermal solutions are important mechanisms that lead to the deposition of base, precious, and volatile metals in epithermal systems. Computer models of these processes with a Broadlands-type geothermal water are presented in a three-part study: boiling, gas phase and metal transport, and acid reactions with metal-bearing waters. Revised and partly rederived thermodynamic data necessary for such a study are presented as an appendix.

Boiling of a Broadlands-type water along alternative P-T-enthalpy paths induces the precipitation of base metal sulfides, sulfosalts, and electrum. The precipitation of base metals results from the pH increase due to CO_2 degassing, and the precipitation of electrum results from the pH increase as well as sulfide loss to the gas phase. Heat transfer to or from wall rocks controls the amount of boiling; thus, because the extent of boiling controls pH, heat transfer controls the precipitated mineral assemblage.

Oxyacids and hydroxides are generally the dominant aqueous species of As and Sb, respectively. At low T, elevated sulfide concentrations, and intermediate pH, As and Sb thiosulfides become dominant. Upon boiling, the precipitation of Cu, Pb and Ag sulfosalts instead of sulfides is most likely at low T and low pH values. Calculated low-T sulfosalt precipitation is consistent with shallow As and Sb mineralization in epithermal systems and also with the commonly observed late precipitation of these metals as T decreases with time. Calculated electrum compositions do not exceed 56 mole % Au. These compositions vary with T but depend mainly on the amount of other Ag-bearing minerals competing with electrum.

Upon boiling, all Hg fractionates into the gas phase from 300° to 101°C. Numerical condensation by cooling the gas phase below 101°C at a constant P induces the precipitation of cinnabar between 80° and 100°C, depending on the Hg concentrations (0.8-800 ppb). As and Sb, however, do not fractionate significantly into the gas phase as long as an aqueous phase is present. Upon 100% boiling of the solution, Sb stays in the dry gas phase down to 220°C where stibnite precipitates, and As down to 130°C where realgar precipitates. The transport of base metals in the dry gas phase requires $T > 400°C$.

The acidification of the boiled Broadlands-type water by acid sulfate waters or by H_2SO_4 produced from magmatic SO_2 leads to the precipitation of Au-rich electrum or Au with Cu sulfides (at 200°, 150°, and 101°C), sulfosalts (at 150° and 101°C), and enargite (at 101°C). Acidification in a hot spring environment at 90°C causes orpiment and stibnite to precipitate. Comparative results between H_2SO_4 and HCl acidification reactions indicate that the replacement of Cu, Pb and Ag sulfides by sulfosalts is driven by pH decrease and is favored by higher sulfide and sulfate activities. The enargite-covellite-tetrahedrite-chalcopyrite downward zoning of acid sulfate-type epithermal deposits can be explained by acidification at constant sulfide activity. Also, the formation of shallow epithermal deposits rich in Au, relative to Ag, can be explained by the reaction at shallow depths between ascending boiling waters and downward percolating acid sulfate waters. (Authors' abstract)

SRETENSKAYA, N.G., RAZINA, M.V. and **BELONOZHKO, A.B.**, 1989, Calculation of thermodynamic properties of phases in the water-potassium chloride system under high parameters using the modified Redlich-Kwong equation: Geokhimiya 1989, no. 3, p. 402-411.

SRIKANTAPPA, C. and **ASHAMANJARI, K.G.**, 1989, Retrograde metamorphism of charnockites in the Bhavani shear zone, Tamil Nadu, India, *in* P.S. Saklani, ed., Metamorphism, ophiolites and orogenic belts: Univ. Delhi, Dept. Geol., Delhi, India, v. 12, p. 55-67.

Indexed under FI. (E.R.)

STALDER, H.A., 1989, Inclusions in quartz crystals from Alpine mineral fissures of the southern part of the Gotthard massif, Switzerland: Mitt. Oesterr. Mineral. Ges., v. 134, p. 73-84 (in German).

The paper is a summary of a lecture at the Austrian Mineral Society—and essentially a general review of previous papers of the author. By means of three examples (Gotthard-road-tunnel, Camperio and Lengenbach), different problems and results of fluid inclusion studies are discussed. The newest mentioned results concern the fluid inclusions found in quartz crystals from the Lengenbach-mine (Binn valley, VS), syngenetic with numerous rare As-sulfosalts.

Some inclusions are unique: H_2O with a high chloride content, CO_2, and an As-sulfide-glass. The latter appears at a well-defined evolution stage of the ore-forming fluid. The As-sulfide-glass has been determined for the first time as a daughter mineral in fluid inclusions (see Hügi, 1988, Fluid Inclusion Research, v. 21, p. 169-170). (Author's abstract)

STANTON, T., HOLLOWAY, J. and **HERVIG, R.**, 1989, Oxygen diffusion in hydrous melts: Resolution of the role of H_2O speciation in the concentration dependence of water diffusion (abst.): Eos, v. 70, p. 501. First author at Dept. Chemistry, Arizona State Univ., Tempe, AZ 85287.

Experiments were conducted to determine the effect of water on the diffusion of oxygen in silicate melts. The portion of the molecular water which is mobile at each concentration level is controlled by the concentration of molecular water and of the anhydrous reactive bridging oxygen sites. (From authors' abstract by E.R.)

STEBBINS, J.F. and **FARNAN, Ian**, 1989, Nuclear magnetic resonance spectroscopy in the earth sciences: Structure and dynamics: Science, v. 245, p. 257-263. Authors at Dept. Geology, Stanford Univ., Stanford, CA 94305.

Detailed knowledge of the structure and dynamics of the materials that make up the earth is necessary for fundamental understanding of most geological processes. Nuclear magnetic resonance spectroscopy is beginning to play an important role in investigations of inorganic solid materials, as well as of liquids and organic compounds; it has already contributed substantially to our knowledge of minerals and rocks, compositionally simplified analogs of magmas, and the surfaces of silicate crystals. The technique is particularly useful for determining local structure and ordering state in crystals, glasses, and liquids, and is sensitive to atomic motion at the time scales of diffusion and viscosity in silicates. New techniques offer promise for increased resolution for quadrupolar nuclei and for extension of experiments to high T and P. (Authors' abstract)

STEELE, I.M., 1989, Compositions of isolated forsterites in Ornans (C3O): Geochim. Cosmochim. Acta, v. 53, p. 2069-2079. Author at Dept. Geophysical Sciences, The Univ. Chicago, 5734 S. Ellis Ave., Chicago, IL 60637.

Luminescing forsterite with FeO between 0.25 and 2.0 wt % occurs as cores of isolated grains and within an Fe-rich porphyritic chondrule in the Ornans (C3O) carbonaceous chondrite. Evidence is presented for growth of euhedral forsterite either from a liquid or gas. (From author's abstract by E.R.)

STEIN, C.L., HIGGINS, K.L. and **MORRISON, R.L.**, 1989, Laser Raman microanalysis of fluid inclusion gases in halite (abst.): Eos, v. 70, p. 1393. First author at Geochemistry Div. 6233, Sandia Nat'l Laboratories, Albuquerque, NM 87185.

Laser Raman microanalysis was used to characterize the composition of the vapor phase in FI in halite. These analyses were performed in conjunction with ongoing studies of halite fluid compositions for the U.S. Dept. of Energy's Waste Isolation Pilot Plant. Samples were selected from clear, colorless, coarsely-crystalline halite from a subsurface depth of ~645 m in the Permian Salado formation in the Delaware Basin, southeastern New Mexico. The FI in the samples examined are large (up to a few mm on an edge), with gas bubbles ~5 to 20% by volume of the inclusion.

Results were obtained using the 514.5 nm argon ion laser line for excitation and the integrated peak areas at 2325 ± 9, 1554 ± 8, and 2916 ± 4 cm^{-1} for N_2, O_2 and CH_4, respectively. No other gases were detected. Gas compositions consisted of either N_2 and O_2 or, more commonly, N_2 and CH_4. Although these results are not quantitative, the molar ratios N_2:O_2 and N_2:CH_4 are constant, and the former is similar to atmospheric N_2:O_2. Variable peak widths and line shifts in the Raman spectra suggest that internal fluid P are slightly greater than atmospheric.

The presence of methane in these inclusions suggests microbial organic decomposition; fluids trapped in at least some of the inclusions examined may have originated early in the diagenetic sequence. The occurrence of O_2 suggests that atmospheric composition may not have changed significantly since the Permian, although contamination by present-day air has not been ruled out. (Authors' abstract)

STEIN, D.J., SPERA, F.J., WEED, H.C. and **RYERSON, F.J.**, 1989, Rheology of silicate and GeO_2 melts and vapor-melt emulsions (abst.): Eos, v. 70, p. 1416.

STENINA, N.G., SOTNIKOV, V.I., KOROLYUK, V.N. and **KOVALEVA, L.T.**, 1988, Microstructural features of hydrothermal vein quartz as an indicator of mineralization: Geokhimiya, no. 5, p. 641-653 (in Russian; translated in Geochem. Int'l., v. 25, no. 12, p. 27-38, 1989). Authors at Inst. Geol. and Geophys., Siberian Div., USSR Acad. Sci., Novosibirsk, USSR.

Measurements have been made on quartz from Mongolian and South Siberian Cu-Mo deposits by transmission electron microscopy, IR spectroscopy and microprobe analysis. Distinctive features of mineralized and barren quartz have been formulated, and new information has been obtained on major aspects of the evolution of hydrothermal mineralized systems. (Authors' abstract)

Includes TEM studies of regions of poorly crystalline or amorphous quartz that were found to be high in trace metals. (E.R.)

STERN, C.R., FUTA, K., KYSER, T.K. and **RUBENSTONE, J.**, 1989, Phlogopite ± amphibole veins in mantle peridotite xenoliths from southernmost South America: Modal metasomatism of the lower continental lithosphere by fluids co-genetic with the alkali basalt hosting the xenoliths (abst.): Eos, v. 70, p. 510. First author at Dept. Geol. Sci., Univ. Colorado, Boulder, CO 80309.

Mono-mineralic Ti-rich phlogopite (TiO_2 = 5-8 wt %) and bi-mineralic phlogopite and kaersutitic amphibole veins cut garnet-lherzolite and -harzburgite xenoliths which have been transported from the base of the South American continental lithosphere in the Quaternary alkali basalts of the Pali-Aike volcanic field of the Patagonian plateau lavas. The isotopic composition of the phlogopite in these veins is $^{87}Sr/^{86}Sr = 0.70343$, $^{143}Nd/^{144}Nd = 0.51286$, $^{206}Pb/^{204}PB = 19.23$, $^{207}Pb/^{204}Pb = 15.62$, $^{208}Pb/^{204}Pb = 38.798$, and $\delta^{18}O = 5.5$. These values are within the range of the Pali-Aike alkali host basalts when $^{87}Sr/^{86}Sr$ is corrected for 0.5 Ma which is less than the 1.25 Ma age of the oldest Pali-Aike lava. These data suggest that the veins formed from fluids in isotopic equilibrium with the alkali basalt magmas being generated in the subjacent mantle. The peridotite xenoliths cut by the veins have a larger range of isotopic composition, with $^{87}Sr/^{86}Sr = 0.7027$ to 0.7044, $^{143}Nd/^{144}Nd = 0.51303$ to 0.51279, and $\delta^{18}O = 5.1$ to 7.8, and they are not in isotopic equilibrium with either the veins or the host basalts. Low but variable δD of the phlogopites, which ranges from -125 to -56, could result from separation of a CO_2-rich vapor phase from the silicate liquids that produced the veins as these liquids rose through the P range in which the solubility of CO_2 in melts decreases. The veins have added significant K and Ti to the continental mantle. (Authors' abstract)

STERNER, S.M., 1989, Geological applications of synthetic fluid inclusions: PhD dissertation, Virginia Polytech. Inst. and State Univ., Blacksburg, VA.

Vapor-saturated solubility relationships in the system $NaCl-KCl-H_2O$ have been determined by experimentally synthesizing FI in quartz in the presence of known brine compositions and then measuring the dissolution T of halite and/or sylvite dxls within the I using a microscope equipped with a heating stage. These data, along with other literature values, have been used in a regression routine to generate a series of equations describing vapor-saturated solubility relations within the halite, sylvite and hydrohalite stability fields. These equations, together with a recently published equation for the ice stability field (Hall et al., 1987), have been used to construct the complete vapor-saturated solubility surface in the $NaCl-KCl-H_2O$ ternary system. The diagram may be used in the interpretation of microthermometric data to determine the compositions of FI approximated by the $NaCl-KCl-H_2O$ system.

P-T conditions inferred from FI in metamorphic rocks often disagree with values predicted from mineral equilibria calculations, suggesting that I formed during early stages of regional metamorphism continue to re-equilibrate during burial and subsequent uplift in response to differential pressure. P-t conditions accompanying burial and uplift were experimentally simulated by forming pure-H_2O I in quartz, and then re-equilibrating the I such that final confining P ranged from 5 kbar above to 4 kbar below the original Pf.

Th of re-equilibrated I indicated densities intermediate between the initial and final P-T conditions. In short-term experiments (seven days) where the initial internal overpressure exceeded 1 kbar, most H_2O I re-equilibrated until their internal P were between ~750 and 1500 bars above the confining P, regardless of the initial P differential. In a long-term experiment (52 days), some I were found to have completely re-equilibrated.

In experiments where the confining P during re-equilibration exceeded the original formation P, the densities of pure-water I increased to values intermediate between the initial and final P-T conditions. Additionally, these I were generally surrounded by a halo of smaller I also of intermediate density and resulting in a texture similar to that previously ascribed to decrepitation resulting from internal overpressure. PVTX relations in the CO_2-H_2O system have been experimentally determined from 2 to 6 kbar and 400° to 700°C for fluid compositions between 12.5 and 87.5 mole % CO_2 using the synthetic FI technique. The method involves trapping CO_2-H_2O fluids of known composition as inclusions in quartz at elevated P and T (P_F and T_F) and then calculating the desired fluid properties using microthermometric data combined with available PVTX data for this system at low P and T.

PTX properties of CO_2-H_2O mixtures were determined from the total Th(total) of FI trapped in the one-fluid phase field. Internal P on the solvus (at Th(total)) were calculated using the equation of state of Connolly and Bodnar (1983) and the I densities as determined above. The P and T of total homogenization of each I defines a point on the solvus unique to that particular bulk fluid composition and density. Thus, the array of many such points determined in this manner delineates the boundary between the one-phase and two-phase fields over a portion of PTX space. (Author's abstract)

STERNER, S.M. and **BODNAR, R.J.**, 1989a, Experimental determination of volumetric properties and phase equilibria in the H_2O-CO_2 system at elevated pressures and temperatures (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 88. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

PVTX relations in the H_2O-CO_2 system have been experimentally determined to 6 kbar and 600°C for fluid compositions between 12.5 and 87.5 mole % CO_2 using the synthetic FI technique. The method involves trapping representative samples of H_2O-CO_2 fluids as inclusions in quartz at elevated P and T and then calculating the desired fluid properties using microthermometric data together with the known fluid bulk composition. Only those inclusions that homogenized to the liquid phase were used, because measured homogenizations to the vapor phase (either CO_2 liquid-vapor or total homogenization) usually yielded spurious results.

PVT properties were determined from measured CO_2 liquid-vapor Th of inclusions grown from a wide range of P, T and compositions. Densities and compositions of both the CO_2 and H_2O-rich phases at Th (CO_2) were determined from available data and the bulk densities of inclusions were then calculated using mass balance considerations involving these individual density values and the bulk fluid composition. Inclusion bulk densities determined at Th (CO_2) ($\leq$31.0°C) were then related to the actual density of the fluid trapped at elevated P and T by a correction for the change in the volume of the inclusion cavity due to thermal expansion and compressibility of quartz. Finally, mean molar volumes (calculated from densities) were expressed as a function of P, T and fluid composition and these data, together with available data from the literature have been used to generate a semi-empirical equation of state for the binary system.

PTX properties were determined from the total Th total. The density of the inclusion fluid at Th total was calculated from the inclusion bulk density Th (CO_2), corrected for thermal expansion for quartz over the T range from Th (CO_2) to Th total. The internal P of the inclusion at Th total was then calculated from the known bulk composition, Th total and the density at Th total. Since the P and T of Th total of each inclusion defines a point on the solvus for that particular bulk fluid composition, the array of individual PTX coordinates determined in this manner define the position of the solvus over a portion of PTX-space. (Authors' abstract)

STERNER, S.M. and **BODNAR, R.J.**, 1989b, Synthetic fluid inclusions—VII. Reequilibration of fluid inclusions in quartz during laboratory-simulated metamorphic burial and uplift: J. Metamorphic Geol., v. 7, p. 243-260. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

P-T conditions inferred from FI in metamorphic rocks often disagree with the values predicted from internal equilibria calculations. These observations suggest that inclusions formed during early stages of regional metamorphism continue to reequilibrate during burial and subsequent uplift in response to differential P. P-T conditions accompanying burial and uplift were experimentally simulated by initially forming pure H_2O inclusions in quartz at elevated T and P, and then reequilibrating the inclusions in the presence of a 20 wt % NaCl solution such that final confining P ranged from 5 kbar above to 4 kbar below the initial internal P of the inclusions at the T of reequilibration.

In all samples reequilibrated at confining P below the internal P, some inclusions were formed that had compositions of 20 wt % Nacl and densities in accord with the final P-T conditions. Additionally, some inclusions were observed to contain fluids of intermediate salinities (between 0 and 20 wt % NaCl). Densities of these inclusions were also consistent with formation at the reequilibration P-T conditions. The remainder of the FI observed in these samples contained pure H_2O and their Th corresponded to densities intermediate between the initial and final P-T conditions. In short-term experiments (7 days) where the initial internal overpressure exceeded 1 kbar, no inclusions were found that contained the original density and none were found to have totally reequilibrated. Instead, most H_2O inclusions reequilibrated until their internal P were between ~750 and 1500 bars above the confining P, regardless of the initial P differential. In a long-term experiment (52 days), inclusions reequilibrated at a lower confining P than the initial internal P displayed Th corresponding to a range in final internal P between 0 kbar (i.e, total reequilibration) and 1.2 kbar above the confining P.

In experiments where the confining P during reequilibration exceeded the initial internal P , densities of pure H_2O inclusions increased to values intermediate between the initial and final P-T conditions. Additionally, these inclusions were generally surrounded by a three-dimensional halo of smaller inclusions, also of intermediate density, resulting in a texture similar to that previously ascribed to decrepitation for internal overpressure. In extreme cases where confining P were 4-5 kbar above the initial P, the parent inclusion almost completely closed leaving only the three-dimensional array of small (≤5 µm) inclusions, the outline of which may be several times the volume of the original inclusions. Groups of such inclusions closely resemble textures commonly observed in medium- to high-grade metamorphic rocks.

Inclusions containing 10 and 42 wt % NaCl solutions trapped at 600°C and 3 kbar were reequilibrated at 600°C and 1 kbar for 5 days in dry Ar to evaluate the importance of H_2O diffusion as a mechanism of lowering the inclusion bulk density. Salinities of reequilibrated inclusions obtained for freezing point depressions and halite dissolution T indicate that original compositions were preserved. Density changes similar to those previously described were noted in these experiments, in inclusions showing no visible microfractures. Therefore, density variations observed in inclusions in this study, reequilibrated under rapid deformation conditions, are considered to result from a change in the inclusion volume, without significant loss of contents by diffusion of leakage. (Authors' abstract)

STERNER, S.M., HALL, D.L. and BODNAR, R.J., 1989a, Experimental determination of the solubility surface in the system NaCl-H_2O and computer program for calculating the compositions of fluid inclusions (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 87. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

Vapor-saturated solubility relations in the system NaCl-KCl-H_2O have been determined using synthetic FI and freezing point-depression measurements. Solubilities in the halite and sylvite stability fields were determined by synthesizing FI in quartz in the presence of NaCl-KCl brines having known compositions and densities corresponding to those along the vapor-saturated solubility surface. Final dissolution T of halite or sylvite within these inclusions were then determined by microthermometric analysis. The known composition of these inclusions, therefore, represents vapor-saturated solubilities at the corresponding T. Phase relations within the ice stability field were determined by measuring the total salinity and NaCl (NaCl + KCl) weight fraction of fluids in equilibrium with ice at different T.

These solubility data, along with other published values, have been regressed using a stepwise multiple regression procedure to generate equations describing T-composition relations for the vapor-saturated solubility surfaces in the halite, sylvite, hydrohalite and ice stability fields. T-composition relations along the five cotectics in this system were determined by simultaneous solution of equations describing solubility surfaces in the adjacent stability fields. The resulting equations have been incorporated into a compute algorithm for determining compositions of FI approximated by the NaCl-KCl-H_2O system. The algorithm is valid for all compositions in the ternary system and requires only the T at which the last two solid phases in the inclusion melt to calculate the total salinity and the NaCl/(NaCl + KCl) weight ratio of the FI, and these data are obtainable during standard microthermometric analysis of the inclusions. (Authors' abstract)

STERNER, S.M., HALL, D.L. and BODNAR, R.J., 1989b, Post-entrapment volumetric and compositional changes in fluid inclusions: Evidence from synthetic fluid inclusions in quartz (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 61-62. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. and State Univ., Blacksburg, VA 24061.

P-T conditions and fluid compositions inferred from FI in metamorphic rocks often disagree with values predicted from mineral equilibria calculations. These observations suggest that inclusions formed during early stages of regional metamorphism continue to reequilibrate during burial and subsequent uplift in response to differential P. In order to quantify this behavior, P-T conditions accompanying burial and uplift were experimentally simulated by forming pure-H_2O inclusions in quartz, and then reequilibrating the inclusions at 700°C in the presence of a 20 wt. % NaCl solution such that final confining P ranged from 5 kbar above to 4 kbar below the original formation P.

In short-term experiments (7 days) where the initial internal overpressure exceeded 1 kbar, no inclusions were found which contained the original density and none were found to have totally reequilibrated. Rather, most H_2O inclusions reequilibrated until their internal P were between ~750 and 1500 bars above the confining P, regardless of the initial P differential. In a long-term experiment (52 days) inclusions reequilibrated at a lower confining P than the original formation P displayed Th corresponding to a range in internal P between 0 (i.e., total reequilibration) and 1.23 kbar above the confining P.

In experiments where the confining P during reequilibration exceeded the original formation P, the densities of pure-water inclusions increased to values intermediate between the initial and final P-T conditions. Additionally, these inclusions were generally surrounded by a halo of smaller inclusions also of intermediate density and resulting in a texture similar to that previously ascribed to decrepitation due to internal overpressure. In extreme cases where confining P were 4 to 5 kbar above the original formation P, the parent inclusion almost completely closed leaving only the array of small (≤3 μm) inclusions the outline of which may be several times the volume of the original inclusion. A group of such inclusions closely resembles textures commonly observed in medium- to high-grade metamorphic rocks.

The results of the present study on the behavior of quartz-hosted synthetic FI during reequilibration at elevated confining P, together with the results of 1 atm stretching studies described by Bodnar et al. (1989, J. Metamorphic Petrology, in press) provide some useful guidelines regarding the strength of FI in quartz. Based on experiments performed on synthetic FI in quartz reequilibrated under high confining P, it is unlikely that a 10 to 30 micron inclusion in quartz will withstand an internal overpressure greater than ~1.5 kbar over geologic time without experiencing a bulk density decrease. Under conditions of internal underpressure greater than ~2 kbar such inclusions will actually experience density increases over geologic time. The result of the above considerations is that isochores calculated for FI from regional metamorphic terranes may represent neither a minimum nor a maximum P-T trajectory. Some 10 to 30 micron inclusions in quartz subjected to internal overpressures at 1 atm confining P can withstand up to 2.5-3.0 kbar internal P for the short period of time of microscope heating run without decrepitation or stretching.

Aside from total decrepitation, stretching or shrinking, another mechanism whereby the bulk density of an inclusion could be altered involves the diffusion of an inclusion component through the quartz inclusion wall. To evaluate the importance of H_2O diffusion as a mechanism of lowering the inclusion bulk density, inclusions containing 10 to 42 wt. % NaCl solutions trapped at 600°C and 3 kbar were reequilibrated at 600°C and 1 kbar for five days in dry argon. Salinities obtained from Tm ice and Tm NaCl of reequilibrated inclusions indicate that original compositions were preserved to within the limits of measurement (±0.15 wt. % NaCl). Density changes similar to those previously described for the pure-H_2O inclusions were noted in these experiments and are therefore considered to result from an increase in the inclusion volume, without loss of contents by diffusion or leakage. Thus, while the densities recorded by these inclusions are no longer meaningful, they are still compositionally representative samples of the fluid present at the time of their formation.

Experiments similar to those discussed above have been performed on quartz-hosted inclusions at a higher T (825°C). Under these conditions, the resultant inclusions are neither volumetrically *nor* compositionally representative of the fluid present during initial trapping. FI having initial compositions of 57 wt. % NaCl were formed by hydrothermally healing fractures in quartz at 1.5 kb and 600°C or 3 kb and 825°C. These inclusions were then reequilibrated for various lengths of time ranging from 12 hrs to 35 days at 825°C and a confining P of 1.5 kb - conditions creating internal overpressures of ~1.5 - 2.5 kbar in the inclusions. Elevated vapor bubble Th in all reequilibrated inclusions indicate that substantial density decreases have occurred. Similarly, elevated Tm NaCl indicate that salinities have increased relative to their initial values, suggesting preferential loss of water from the inclusion via diffusion. For example, inclusions initially trapped at 3 kb and 825°C had initial Tm NaCls of 480 ± 3°C. Following reequilibration for 108 hrs, inclusions in this sample displayed a range of Tm NaCl from 497 to 635°C corresponding to a range in salinity from 59.4 to 79 wt % NaCl. To insure that the elevated Tm NaCls were not solely the result of the increased volume of the water-rich vapor phase, inclusions were prepared from a 57 wt % brine at 1.5 kb and 825°C. Tm NaCls recorded in these inclusions (485 ± 3°C) were only slightly greater than those described above for inclusions trapped at 3 kb and 825°C.

Inclusions in each reequilibrated sample display a strong negative correlation between salinity and inclusion volume. Also, in inclusions of the same size, those which have been subjected to the reequilibration conditions for the longest times display the highest Tm NaCl. These observations are consistent with diffusional loss of water from the inclusions into the surrounding quartz in that the relative amount of water lost should increase as the surface area-to-volume ratio of the inclusion increases, and for inclusions having the same volume the water loss should be maximal for those reequilibrated of the longest time. Using visual estimates of inclusion volumes, salinity changes within these inclusions determined from Tm NaCl, density data for concentrated brines at elevated P and T from Bodnar (1985, PhD dissertation, Penn. State Univ., 183 pp.), and assuming that changes in the inclusions may be solely attributed to the diffusional loss of water, one can calculate the average mass of H_2O lost per unit area of the inclusion wall surface per unit time. Such a calculation for the inclusions in this study yields a flux of $2.2*10^{-11}$ gm/cm^2*sec. (Authors' abstract)

STERNER, S.M., HALL, D.L. and BODNAR, R.J., 1989c, Fluid immiscibility in geologic environments: Interpretation of fluid inclusion data using available fluid phase equilibria (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-180. Authors at Virginia Polytech. Inst. & State Univ., Blacksburg, VA.

There is increasing evidence, both natural and experimental, that immiscibility exists in saltwater and CO_2-saltwater fluid systems over a substantial portion of geologically relevant P-T space. Fluid immiscibility has been proposed in a number of metamorphic terranes based on the occurrence of fluid inclusions that display a bimodal distribution of compositions, presumably resulting from the presence of two distinct fluids coexisting at equilibrium at the time of trapping. Formation conditions inferred for these inclusions have then been used to help constrain the P-T evolution of the rocks. The compositions of individual inclusions cited as evidence for fluid immiscibility, however, are often incompatible with known phase relations of the appropriate systems and thus are inconsistent with the assertion of simultaneous trapping. This situation is particularly apparent in studies of natural systems where fluid immiscibility has been postulated based on data from H_2O-CO_2-NaCl bearing fluid inclusions. Using presently available data on the pressure-volume-temperature-compositions (PVTX) relations in this system, we will outline those criteria which must be met in order to invoke the simultaneous trapping of coexisting equilibrium liquid and vapor phases in fluid inclusions at elevated T and P.

The extent of the two-phase region in a one-component system is restricted to a univariant curve in P-T space along which liquid and vapor may coexist at equilibrium. In other words, the simultaneous trapping of fluid inclusions containing both phases at equilibrium can only occur over a very restricted set of P-T conditions. With the addition of a second component, the two-phase region becomes a divariant field in P-T space. In a binary system such as NaCl-H_2O or CO_2-H_2O at fixed P and T, the compositions of the liquid and vapor phases coexisting at equilibrium are uniquely specified. Furthermore, any fluid at this P and T having a bulk composition between these two values is unstable and will exsolve into distinct liquid and vapor phases, whereas bulk fluid compositions lying outside this range remain stable one-phase fluids. Of particular interest is that in P-X or T-X projections of binary systems such as NaCl-H_2O or CO_2-H_2O, *the mixing lines are the tie lines*. Once P and T are fixed, the compositions of the coexisting liquid and vapor phases are given by the appropriate tie line on a P-X or T-X projection. This is not necessarily true for ternary and higher order systems in general, and it is almost never true for the system H_2O-CO_2-NaCl.

In studies of fluid inclusions from the H_2O-CO_2-NaCl system, the presence of inclusions containing large amounts of CO_2 together with those containing small amounts of CO_2 but having the same relative salinity (NaCl/(NaCl+H_2O)) has often been taken as evidence for fluid immiscibility at the time of inclusion trapping. The intersection of isochores thought to represent the two types of inclusions have then been used to estimate P and T of trapping. However, by consideration of the available PTX data for this ternary system, it is evident that when the two types of inclusions have the same relative salinity, the possibility of simultaneous trapping is actually precluded and, thus, the assertion of fluid immiscibility as well as the P-T estimate so derived are invalid. In fact, several lines of evidence suggest that during unmixing of fluids in this ternary system, NaCl is strongly partitioned into the liquid phase so that the relative salinity (NaCl/(NaCl+H_2O)) of the liquid will be many times greater than that of the vapor.

Inclusions formed at a fixed P and T in the presence of immiscible H_2O-CO_2-NaCl fluids will display a range in both composition and density depending on the liquid to vapor ratio in the inclusion at the time of trapping. Those which have trapped only the liquid phase will homogenize to the liquid upon reheating to their Tf. Those which trap only the vapor should also homogenize (to the vapor) at this T. In the latter inclusions, however, due to the wetting characteristics of the liquid phase which forms a thin, optically invisible rim at high T, an "apparent Th" can be observed several hundred degrees below true Th. In the system H_2O-CO_2-NaCl, this effect is important in measuring both CO_2 liquid/vapor homogenization to the vapor phase and total inclusion homogenization to the vapor. Thus, failure of these two end-member inclusion types to exhibit simultaneous homogenization does not rule out the possibility of boiling. Inclusions that trap mixtures of the coexisting liquid and vapor phases will contain fluids having bulk compositions and densities intermediate between that of either the liquid or the vapor. Because they did not trap a homogeneous, one-phase fluid, their true Th will necessarily be higher than their Tt, but again this may not be observable in the vapor-rich ones. (Authors' abstract)

STOCKEY, J.R. and **McLELLEN, Eileen**, 1989, The use of fluid inclusions as a petrographic tool in polymetamorphic and deformed rocks (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 63. First author at Dept. Geol., The George Washington Univ., Washington, DC 20052.

Conventionally FI in polymetamorphic and deformed rocks have not been considered useful due to (1) small grain and inclusion size and (2) leaking and reequilibration due to later events. However, populations of inclusions can be defined on size, shape, occurrence, liquid/vapor ratio, and orientation, especially if these characteristics can also be associated with specific generations of minerals which have been tied to a sequence of metamorphic and/or deformation events. Once defined, the occurrence, change in and elimination of these populations become an additional source of data concerning the history of the rock unit.

Example 1: The Brevard Zone at Rosman, N.C. The original inclusion population in the Henderson Gneiss is modified and largely destroyed during deformation in the BZ, by ductile deformation processes such as dislocation creep and glide. This results in creation of small grains of inclusion-free quartz and decrepitated, leaked and isolated remnants of original populations. In the ultramylonite the original population is totally destroyed but a second population appears, trapped during recrystallization in the presence of fluid along planes of localization of strain during deformation. Lastly a third population occurs, postdating all recrystallization and ductile deformation, accompanying extensional fracturing.

Example 2: The Quetico Fault, Quetico/Wabigoon subprovince boundary, Canada. Our work has focussed on determining the crustal levels at which deformation associated with the fault occurred. FI samples were collected both from deformed "country" rocks and from veins associated with the fault zone. FI populations were identified petrographically and chronology of these populations was determined both from field occurrence (position in regional structural sequence) and from their relationship to deformation microstructures. Isochores from each population were used to constrain the P-T conditions of each stage of deformation. Independent estimates of T were obtained using feldspar geothermometry on unrecrystallized grains. Hence P could be determined. Results indicate that deformation occurred at depths ranging from 20-25 km (mylonite formation) to 10-12 km (cataclasis). Only the end portions of the fault zone show an overprinting brittle event at 12 km. The range in levels of deformation suggests i) that the fault is a crustally penetrative structure possibly representing a major tectonic boundary, and ii) that the fault structure itself has undergone regional folding. (Authors' abstract)

STOFFREGEN, R.E., **RYE, R.O.** and **WASSERMAN, M.D.**, 1989, Experimental determination of ^{18}O (sulfate-site) and D fractionations between alunite and water at 250 to 450°C (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A155.

STOLPER, E., 1989a, Experimental and analytical constraints on the degassing of basaltic and rhyolitic magmas (abst.): Continental Magmatism Abstracts, Santa Fe, IAVCEI, New Mexico Bureau of Mines and Mineral Res. Bull. 131, p. 257. Author at Div. Geol. Planet. Sci., Caltech, Pasadena, CA 91125.

I will report on the results of experiments conducted by me and my colleagues to determine (1) the solubilities of CO_2 and H_2O in basaltic and rhyolitic melts at P up to several kilobars; (2) the speciation of CO_2 and H_2O in glasses quenched from basaltic and rhyolitic melts; (3) isotopic fractionations between vapor and C- and H-bearing species in rhyolitic melts; and (4) the diffusivities of C- and H-bearing species of rhyolitic melts and glasses.

These experimental results will be compared with results of analyses of the concentrations and isotopic compositions of H_2O and CO_2 in volcanic glasses from a variety of settings to set constraints on the behavior of volatiles in high-level magmatic systems. Some important conclusions include: (1) Dissolved CO_2 and H_2O in obsidian from pyroclastic rocks and lava flows from the ca. 1340 A.D. eruption of the Mono Craters, CA, generally decreased as the eruption proceeded. Results for obsidian clasts from the pyroclastic deposits suggest that the parent magma was relatively rich in CO_2 (perhaps from degassing of basaltic magmas underplating the silicic magmatic system) and that degassing during this early phase of the eruptive sequence approached closed system behavior.

Hydrogen isotopic data suggest a transition to open system degassing late in the eruptive sequence, perhaps coinciding with a transition from explosive to quiescent eruptions. (2) Analyses of glass inclusions from phenocrysts from the plinian and ash-flow deposits of the Bishop Tuff, CA, indicate that H_2O was enriched and CO_2 was depleted upwards in the preeruptive magma. This is most easily understood if the magma was saturated with a CO_2-H_2O vapor throughout. Crystallization of a vapor-saturated parent liquid similar to the ash-flow inclusions would generate residual liquids enriched in H_2O and depleted in CO_2 similar to the plinian inclusions. Assuming vapor saturation, P of entrapment of the inclusions are typically 1.5-2.5 kbar. (3) Submarine basaltic glasses are often supersaturated with respect to CO_2 at their eruption depths, suggesting that magma transport from depth can be so rapid that degassing is incomplete and kinetically limited. In such cases, vesicle gases may be enriched preferentially in rapidly diffusing components (e.g., light rare gases) and concentrations profiles in slower components (e.g., H_2O and CO_2) are to be expected adjacent to vesicles and may be used to set constraints on time scales of magma ascent. (Author's abstract)

STOLPER, Edward, 1989b, Temperature dependence of the speciation of water in rhyolitic melts and glasses: Am. Mineral., v. 74, p. 1247-1257.

STOLZ, A.J. and **DAVIES, G.R.,** 1989, Metasomatized lower crustal and upper mantle xenoliths for north Queensland: Chemical and isotopic evidence bearing on the composition and source of the fluid phase: Geochim. Cosmochim. Acta, v. 53, p. 649-660. First author at Dept. Geol., Univ. Tasmania, Box 252C, G.P.O., Hobart, Tasmania, 7001, Australia.

A diverse range of ultramafic and mafic granulite xenoliths from cone #32, north Queensland display mineralogical and chemical evidence for enhanced fluid activities in the lowermost crust and uppermost mantle. Metasomatism of spinel lherzolite, garnet and spinel websterite and garnet granulite produced variable amounts of amphibole ± mica, locally resulting in development of hornblendite as the end-product of reaction between spinel websterite and C-O-H fluids. In contrast, associated felsic and 2-pyroxene granulite xenoliths have remained relatively unaffected. The garnet granulites and spinel websterites are interpreted as products of underplating of the lower crust by Cenozoic magmatic activity, whereas Nd-Sr isotope systematics for the 2-pyroxene and felsic granulite xenoliths suggest that they may be of Proterozoic age.

The development of amphibole and mica in the mafic and ultramafic xenoliths was accompanied by increases in TiO_2, Na_2O, K_2O, Al_2O_3, Sr, Ba, Zr, Nb, LREE and Fe_2O_3/FeO, and decreased MgO, SiO_2, Cr and Ni. Virtually anhydrous spinel websterite xenoliths have $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ almost identical to amphibole-rich variants and hornblendite, and very similar values to the host nepheline mugearite and an amphibole megacrysts. The chemical and isotopic data suggest that the metasomatism is a relatively young feature caused by oxidized fluids exsolved from alkaline magmas similar to the host as they ascended through the lithosphere. This style of metasomatism is considered a relatively localized phenomenon which is unlikely to provide an important contribution to the source region is of alkali basaltic magmas. (Authors' abstract)

STONE, W.E. and **FLEET, M.E.,** 1989, Phase relations of nickeliferous monosulphide solid solution in megacrysts from Mt. Shasta, California (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-33. Authors at Dept. Geol, Univ. Western Ontario, London, Ontario N6A5B7.

Nickeliferous monosulphide solid solution (mss), pentlandite, chalcopyrite and pyrrhotite occur in basalt and andesite tephra in a cinder cone on Mt. Shasta, California, as micrometer-size subspherical polymineralic aggregates with iddingsite-like material within olivine and pyroxene megacrysts and dacite glass, and along fractures. The mss is S-rich and occurs as two intergrown lamellar phases: mss(1) with 6 to 12 at. % Ni and mss(2) with 14 to 20 at. % Ni. Pentlandite with pyrrhotite is Fe-rich, whereas that with mss is Ni-rich, and is S-rich. The proportion of sulphide minerals present varies, but those within olivine contain more mss(2) and less chalcopyrite.

The miscibility gap in the mss compared to that determined in low T experimental studies is on the Fe-rich side of the Ni-Fe-S system and the mss(2) field does not extend to the Ni-rich side. The extent of unmixing of the mss is variable, even within a single sample, but this could reflect annealing on a cooling gradient. Although the subspherical shape of the sulphide aggregates, consistency in bulk composition and consistency of bulk sulphide and olivine composition with partition data suggest an origin through sulphide liquid immiscibility, contribution of the iddingsite-like material to the subspherical shape, presence of many aggregates along fractures and in dacite glass, and their sporadic distribution contradicts sulphide liquid immiscibility and suggests and origin through subsolidus processes, such as degassing and metasomatism. (Authors' abstract)

STONE, W.E., FLEET, M.E. and MacRAE, N.D., 1989, Two-phase nickeliferous monosulfide solid solution (mss) in megacrysts from Mount Shasta, California: A natural laboratory for nickel-copper sulfides: Am. Mineral., v. 74, p. 981-993. Authors at Dept. Geology, Univ. Western Ontario, London, Ontario N6A 5B7, Canada.

Sulfide spherules in basalt and andesite tephra from a cinder cone on Mount Shasta, California, have been characterized in detail. The nickel-iron-copper sulfides occur in micrometer-sized subspherical polymineralic aggregates with an unidentified opaque hydrous iron silicate within olivine and pyroxene megacrysts, along fractures in the megacrysts, and in altered glass. The subspherical shape of the sulfide mineral aggregates and the consistency of bulk sulfide and olivine compositions with experimental high-temperature partitioning data suggest an origin through sulfide liquid immiscibility. However, the presence of many sulfide aggregates along fractures and in dacitic matrix and the variable bulk sulfide composition contradict an interpretation of sulfide liquid immiscibility and suggest instead that high-temperature subsolidus processes, such as degassing, S infiltration along fractures, and Ni diffusion, may have been important. (From authors' abstract by E.R.)

STUWE, K., 1989, Pressure-temperature-time paths and gold mineralisation: 79th Annual Meeting Geologische Vereinigung, Mineral Deposits; Leoben, Austria, 15-18 Feb. 1989, Terra Abstracts, v. 1, no. 2.

Structural work in the past has shown that turbidite hosted auriferous vein deposits formed worldwide (a) after the principal cleavage development in mid-greenschist metamorphic rocks; (b) near or just after the ductile-brittle transition during cooling and uplift; and (c) after or together with the intrusion of post-tectonic granitoids. Paralleling laboratory studies have shown with evidence from FI, stable isotopes and vein geochemical studies that such deposits generally formed (a) at ~250-400°C which is near the metamorphic peak T of the host rocks; (b) from fluids with isotopic compositions consistent with a metamorphic derivation; and (c) from fluids which must have derived their Au contents from enriched sediments or different source rocks.

[From] this partly contradictory field and laboratory evidence has risen much confusion about the interpretation of the origin of the Au, much of which is caused by the descriptive nature of many studies of Au deposits which often lack attempts for large scale tectonic interpretations of the mineralised terrain. This paper emphasizes the importance of the asynchronous nature of the piezothermal array for the liberation of hypothetically mineralised fluids. (From authors' abstract by E.R.)

SUGAKI, A. and SHIMADA, N., 1989, Tin-bearing polymetallic ores from the Dachang mine, China, and their mineralizations (abst.): Min. Geol., v. 39, p. 58-59 (in Japanese, translated by S. Taguchi). Authors at Kyushu Univ.

The Dachang deposits, Guangxi Zhuangzu, China, are embedded in Middle to Upper Devonian formations. Ore bodies consist of skarn type (Cu, Zn), vein type (W, Sb), network type (Sn), and strataform type (Sn) deposits. Sn mineralization is found in the last two types, with the strataform type cut by the network type.

The strataform deposits appear syngenetic, and the pyrite-pyrrhotite ore contains minerals such as sphalerite, cassiterite (0-0.6 mol % FeO), stannite (11-14 mol % Cu_2ZnSnS_4), arsenopyrite, quartz, calcite, and sericite. In contrast, the ore of the network deposits consists mainly of pyrite and sphalerite and contains cassiterite (0-5.9 mol % FeO), stannite-kesterite (25-84 mol % Cu_2ZnSnS_4), freibergite, jamesonite, boulangerite, franckeite, pyrargyrite and other sulfosalts. $\delta^{34}S$ values of pyrite, sphalerite and pyrrhotite from the network deposits range from -4.5 to +3.0‰, and that from the strataform deposits -4.5 to +2.0‰.

Fluid inclusions in quartz and cassiterite from the network type deposits have Th of 300-400°C and 3.5-9.7 eq. wt % NaCl; fS_2 is estimated to be 10^{-11} to 10^{-7} atm from the mineral paragenesis and FeS content of sphalerite (7.6-21.2 mol %). (Authors' abstract)

SULGAN, Miloslav and HURAI, Vratislav, 1989, Ore-bearing factors of intrusive bodies in relation to porphyry copper-molybdenum ore deposits: Mineralia slovaca, v. 21, p. 123-130 (in Czech., English abstract). First author at Geologicky ústav CGV SAV, Horná 17, 974 01 Banská Bystrica, Czechoslovakia.

The paper sketches crystallization path and phase changes during the cooling of a hypothetical stock-shaped intrusive body of quartz monzonite under various thermodynamic conditions. Namely, the process of ore-bearing fluid generation is analyzed in relation with the depth of intrusive body emplacement. In the case of shallower emplacement (2-6 km), fluids with high Cu content are generated and subsequently heterogenized into a highly-concentrated liquid and low-concentrated gaseous phase of low concentration. In depths exceeding 6 km, conditions are suitable for the release of fluids with high Mo concentration, and the heterogenization into a liquid and gaseous phase is absent. The discussed model is in accordance with the character of fluid inclusions from typical porphyry Cu and Mo ore deposits. (Authors' abstract)

SUSHCHEVSKAYA, T.M., KALINICHENKO, A.M. and **KNYAZEVA, S.N.,** 1989, Determination of fluid inclusion water content in minerals by proton magnetic resonance method: Geokhimiya, 1989, no. 10, p. 1460-1465 (in Russian).

The possibility of using proton magnetic resonance (PMR) for analysis of H_2O content of fluid inclusions in different minerals (quartz, fluorite, topaz and calcite) has been demonstrated. The results of analyses of standard samples (Table 1) showed reasonably good reproducibility (characterized by S_r [standard deviation?] = 0.06-0.14).

The results for cassiterite samples are not so reliable because of usual presence of paramagnetic admixtures (e.g., Fe_2O_3, $FeMnWO_4$). The comparison of PMR data for a group of samples with the results previously obtained by gas chromatography (with thermal decrepitation of inclusions) demonstrated good agreement for nearly all samples but cassiterites. Compared to other methods of water content determination, such as gas chromatography and mass spectrometry, PMR technique has the same level of sensitivity [but] possesses two important advantages: It is nondestructive (the sample can be used for subsequent study) and selective (presence of hydrogen atoms from other substances does not affect the results of determination of liquid-water content). (Abstract by T. Sushchevskaya)

Table 1. Water content in fluid inclusions in quartz (standard samples).

	PMR$^+$			Gas chromatography			t-criterion	
Sample	wt %	n	S_r	wt %	n	S_r	found	critic (P = 0.95)
Q2011 quartz from Sn-W veins, Iultin, Chukotka	0.099	10	0.09	0.095	20	0.05	1.36	2.05
WK-1 quartz from vein with fluorite Erzgebirge, DDR**	0.070	6	0.14	0.078	4	0.06	1.69	2.31
Q-74 quartz from barren quartz vein Sarykul' Kazakhstan, USSR	0.095	5	0.06	0.093	20	0.09	0.65	2.07

$^+$ Pure crushed samples ~0.5 g were washed by deionized water, then dried (T ~ 105°C); PMR spectra were obtained using CXP-270 Brucker (υ_o = 200.13 MHz) and PYa - 2301 υ_o = 16.0 MHz) at T = 20°C.

** Provided by Dr. W. Klemm, Bergakademie, Freiberg, DDR.

SUSHCHEVSKAYA, T., KOKINA, T. and **KORSAKOVA, N.,** 1989, Use of the potentiometric method for sulfide determination in fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 64. Authors at V.I. Vernadsky Inst. Geochem. and Anal. Chem., USSR Acad. Sci., Moscow, USSR.

Estimation of sulfide (S(II)) concentration in ore-forming solutions is of interest both because of formation of sulfide mineralization and because of participation of sulfur in redox reactions which go on in hydrothermal solutions during formation of ores of various types. Conventional and the injection flow potentiometric method were used to determine S(II) content in the extracts from FI. To this end standard equipment produced in Hungary was used.

Extraction of the inclusion fluids was carried out during grinding of the clean crushed (0.25-0.5 mm) minerals in an agate mortar in NaOH solution (0.1-1.0 M). Rate of sulfide oxidation reactions being very low it was possible to perform extraction without adding reducing agents in the presence of atmospheric air and not obligatory in inert gas atmosphere, as it was proposed by several authors. The flow injection determination of S(II) ions with micro-flow-through membrane ion selective electrode was performed on injection of 10-100 µl of the analyzed solution in flow of carrier solution (0.1 NaOH, optimal flow velocity in the range 6-9 ml/min). This method can be used for the solution with S(II) concentration $5 \cdot 10^{-6}$ - 10^{-1} M (standard deviation S_σ 0.05-0.07).

S(II) concentration values of the order 10^{-3} M are most typical for the stage of Sn mineralization deposition, while for the sulfide and polymetallic mineralization concentrations exceeding 10^{-2} M are usual. (Authors' abstract)

SVERJENSKY, D.A., 1989, The diverse origins of Mississippi Valley-type Zn-Pb-Ba-F deposits: Chron. rech. min., no. 495, p. 5-13 (in English). Author at Dept. Earth and Planetary Sciences, The Johns Hopkins Univ., Baltimore, MD 21218.

Intensive studies of the classic Mississippi Valley-type deposits in North America during the last 10 years have demonstrated that, even though the deposits constitute a well-defined class, a number of significant differences exist between the major districts. In addition, some of the major districts show similarities to other kinds of sediment-hosted base-metal sulfide ore deposits. For the overall class of deposits, it appears that the basinal brine hypothesis of ore formation is generally applicable. However, in detail, the genesis of individual major districts may differ significantly. For example, in the southeast Missouri district, the characteristic scarcity of petroliferous materials, the absences of native sulfur and barite, the abundance evidence of repetitive precipitation and dissolution of sphalerite and galena, the highly varied Pb and S isotopic compositions of the fluids, and the T (typically ~120°C) are consistent with ore formation by precipitation of about 1 ppm metal sulfide from basinal brines that transported base metals as metal-chloride complexes together with H_2S under conditions of acidic pH and high total dissolved CO_2 concentrations. Other districts (e.g., Pine Point, Kentucky-Illinois, Upper Mississippi Valley) with different relative mineral abundances, textures and isotopic systematics may well have a different genesis with respect to basinal sources, migration paths, and transport and precipitation mechanisms. (Author's abstract)

SZTACHO, Petr, 1989, Fluid inclusion study in the minerals of the Au-W deposit Orlik near Humpolec in the core of the Bohemian massif (abst.): Fluids in Geological Processes, Abstracts, Comenius Univ. Geol. Inst., Bratislava, CSSR, 30 May, 1989, p. 12. Author at Geol. Survey, Malostranske nam. 19, 118 21 Praha 1, CSSR.

The presence of Au mineralization is one of the significant metallogenic features of the Bohemian massif. The Orlik locality near Humpolec, ca 100 km ESE from Prague, is characterized by the occurrence of Au mineralization with scheelite and sulphides in high metamorphic rocks of the Moldanubicum in the core of the Bohemian massif near the contact with Variscan Central Moldanubian Pluton. Native Au of high fineness intergrowths with Bi and maldonite, and is accompanied by scheelite and sulphides.

FI were studied in apatite, scheelite and quartz. The methods of microthermometry and Raman spectroscopic analyses were applied. The following types of FI were distinguished: H_2O-CO_2 (CH_4, N_2, H_2S); H_2O-CH_4(N_2); H_2O (CH_4); and H_2O.

Scheelite precipitated from H_2O (CH_4) solutions of a salinity up to 10 wt % NaCl eq., and the T interval of deposition was 375-385°C.

Formation T agree with upper T stability limit of maldonite (Au2Bi), which occurs in the ore-bearing quartz. This fact suggests that the deposition of maldonite occurred after precipitation of scheelite from solutions in which water and methane ($\pm N_2$) were dominant components. (Author's abstract)

TADA, Rynji and SIEVER, Raymond, 1989, Pressure solution during diagenesis: Ann. Rev. Earth Planet Sci., v. 17, p. 89-118.

Pertinent to studies of inclusions in overgrowths and other diagenetic phases. (E.R.)

TAKASHIMA, Isao, HONDA, Sakuro and RAKSASKULWONG, Manop, 1989, Alteration and hydrothermal system model of the San Kamphaeng geothermal area, northern Thailand: Geothermal Resources Council, v. 13, p. 201-206.

Indexed under FI. (E.R.)

TANER, Havva, WILLIAMS-JONES, A.E. and WOOD, S.A., 1989, The nature, origin, and physicochemical controls of hydrothermal Mo-Bi mineralization in the Cadillac and Preissac deposits, Quebec (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-70. Authors at Dept. Geol. Sci., McGill Univ., Montreal, Quebec H3A 2A7, Canada.

The Cadillac and Preissac Mo-Bi deposits are hosted by subvertical and subhorizontal quartz-K-feldspar-muscovite veins in the leucoadamellite phase of the Archean, Preissac batholith. The quartz in these veins contains four main types of FI: aqueous L and LV inclusions, aqueous-carbonic LLV inclusions, carbonic LV inclusions, and solid-bearing, aqueous L and LV inclusions. Aqueous inclusions display 3 distinct salinity groupings with peaks of 5, 18, 26 wt % NaCl eq. respectively. Leachate analyses show that the bulk fluid contained significant concentrations of Na, K, Ca, Li, Ni, and Cl. The most abundant components are Na and Cl. The chloride ion concentration is considerably higher than predicted by the combined charge of the measured cations. This difference can be explained by the room T H concentration computed from estimates made of the high T pH. The carbonic liquid phase in carbonic and carbonic-aqueous inclusions melts between -56.6°C and -58°C indicating that it consists largely of CO_2. The following minerals have been tentatively identified in the solid-bearing aqueous inclusions using an SEM equipped with an EDS analyzer: calcite, hydrophilite, muscovite, millerite, and halite. FI microthermometry and oxygen isotope analyses of quartz-muscovite pairs indicate that the T at the time of ore deposition was approximately 425°C and that the P was between 680 and 740 bars. A model is proposed in which molybdenite was deposited as a consequence of decreasing T and/or P from CO_2-bearing high to moderate salinity fluids of mixed magmatic-meteoric origin that evolved through interaction with volcanic (komatitic) and sedimentary country rocks. (Authors' abstract)

TANGER, J.C., IV and PITZER, K.S., 1989, Thermodynamics of NaCl-H_2O: A new equation of state for the near-critical region and comparisons with other equations for adjoining regions: Geochim. Cosmochim. Acta, v. 53, p. 973-997. First author at Chem. Thermody. Div., Center for Chem. Physics, Nat'l. Inst. Standards & Tech., Gaithersburg, MD 20899, USA.

A new equation of state for NaCl-H_2O is based on an expansion around the critical point of pure H_2O. Only a few simple terms relate to the NaCl content, but the complete equation of Haar et al. (1984) is used for H_2O. Three T-dependent parameters are adjusted to fit the entire vapor-liquid coexistence surface from 250 to 600°C. One further T-dependent function relates the chemical potential of NaCl to that of the solid. Appropriate derivatives of the parent function for the Helmholtz energy then yield the density and the full array of thermodynamic properties. While full agreement with all experimental data within their uncertainties is not attained, the agreement is good throughout the range 300 to 600°C, V + L saturation P to one kbar and from the vapor composition at the three-phase line to that of the corresponding liquid. Comparisons with published equations valid for liquid-only or vapor-only conditions also show satisfactory agreement. (Authors' abstract)

TAPP, J.B. and PREZBINDOWSKI, D.R., 1989, Dynamic alteration of fluid inclusion homogenization temperatures: A fracture mechanics analysis (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A357. First author at Dept. Geosciences, Univ. Tulsa, 600 S. College Ave., Tulsa, OK 74104.

Fluid inclusions respond mechanically to both thermal and tectonic stress by volume change (stretching) which shifts and spreads Th. Fluid inclusion response can be described quantitatively in terms of remote and thermal stresses, and rheology of the crystal using classical elastic-plastic fracture mechanics. Thermal and tectonic stresses result in predictable changes in volume that depend on the following: (1) Mineralogy (yield stress and anisotropy). (2) Fluid inclusion shape (stress concentration in the vicinity of the fluid inclusions). Large axial ratio shapes and sharp corners concentrate significant stress in the crystal around the inclusion (on the order of 3-8 times the remote or thermal stress). (3) Fluid inclusion size (stress concentration shows a limited increase with size). (4) Type of load (thermal stress can be treated as simple extension, tectonic stress can be treated as shear—mixed stress requires more complex models).

Application of classical fracture mechanics theory to fluid inclusion dynamics yields a numerically valid method for the forward prediction of Th change with thermal and tectonic stress, and provides a means to normalize polymodal and shifted (increased) Th from stretched fluid inclusion populations. The shift and spread in reported fluid inclusion Th is a predictable result of the dynamic change in the volume of fluid inclusions according to shape, size, orientation in a crystal and type of stress. This shift and spread can be corrected, giving an indication of the maximum T that the rocks containing the fluid inclusions have experienced. Theoretical prediction closely matches a significant worldwide correlation of fluid inclusion Th with depth of burial. (Authors' abstract)

TATSUMI, Yoshiyuki, 1989, Migration of fluid phases and genesis of basalt magmas in subduction zones: J. Geophys. Res., v. 94, no. B4, p. 4697-4707. Author at Dept. Geol. and Min., Kyoto Univ., Kyoto, Japan.

Dehydration and hydration reactions in both the downgoing lithosphere and the overlying mantle wedge have been examined in order to understand the role of H_2O in the production of magmas at convergent plate boundaries. (From author's abstract by E.R.)

TAYLOR, W.R. and **FOLEY, S.F.**, 1989, Improved oxygen-buffering techniques for C-O-H fluid-saturated experiments at high pressure: J. Geophys. Res., v. 94, no. B4, p. 4146-4158.

THAN, Zaw and **TAKENOUCHI, Sukune**, 1988, Fluid inclusion study of Jeonui deposit and Samkwang deposit, Republic of Korea (abst.): Abstracts, Joint Mtg. Min. Soc. Jap./Soc. Min. Geol. Jap./Jap. Assoc. Min., Pet., Econ. Geol. (in Japanese, translated by Y. Seki). Authors at Fac. of Eng., Univ. Tokyo.

Fluid inclusions of vein quartz taken from the Jeonui Au-Ag deposit and the Samkwang Au-Ag deposit were studied. Fluid inclusions of the Jeonui deposit are maximum 40 µm in diameter; most are liquid-rich but some are vapor-dominant. Less than 10% of all have dxls appearing to be halite. Th ranges from 200 to 290°C, with peaks of 240, 205 and 280°C in descending order of abundance. Fluid inclusions from the Samkwang deposit are maximum 40 µm; most are vapor-rich and never contain dxls. Th ranges from 140 to 190°C, with a peak of 150°C. Analytical results of gas collected by the vacuum decrepitation method are shown in the table. CO_2 is a dominant component. For the rest, CH_4 and N_2 are major components. (Authors' abstract)

Summary of the gas analyses

	Jeonui			Samkwang		
	Min.	Max.	Average	Min.	Max.	Average
XCO_2	0.81	0.93	0.87	0.82	0.97	0.91
XCH_4	0.05	0.15	0.10	0.01	0.12	0.05
Total gas molality	1.55	6.94	3.84	0.59	2.73	1.50

THIBAULT, Y. and **EDGAR, A.D.**, 1989, Modelling of Ca-metasomatism in a model pyrolite up to 30 kbar: Implications on the importance of Ca relative to K and Na metasomatism (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-50.

THOMAS, A.V., PASTERIS, J.D., BRAY, C.J. and SPOONER, E.T.C., 1989, H_2O-CH_4-NaCl-CO_2 inclusions from the Tanco granitic pegmatite: Estimates of internal pressure and composition from microthermometry, laser Raman spectroscopy and gas chromatography (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 65. First author at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

Inclusions in tourmaline from a metasomatized part of the footwall amphibolite of the Tanco pegmatite, S.E. Manitoba were investigated by Thomas and Spooner (1988, Geochim. Cosmochim. Acta, 52, 1065-1075). Microthermometry (MT) suggested that the vapor phase (at room T) of these inclusions was dominated by CH_4 (critical points (c.p.'s) for inclusions = -79.1 ± 1.4°C, c.p. pure CH_4 = -82.1°C; clathrate melting at 12.2 ± 1.6°C). A method was proposed to estimate aqueous phase salinity which used the determination of the inclusion isochore at Tm Clath. The isochore also gave an estimate of the internal P as a test of the salinity estimation method since the specific spectral position of the Raman band for CH_4 is sensitive to gas P in an inclusion (Fabre and Couty, 1986, C.R. Acad. Sci. Paris, 303, Serie II, no. 14, 1305-1308). An Ar lamp was used to calibrate the spectrometer to ensure accurate determination of CH_4 band position. Fourteen inclusions were selected for analysis by LRS and MT. In 4 of these the signal was too weak for accurate determination of CH_4 peak position. In 10, however, there were good peaks for CH_4 but not for other gases (N_2, CO_2, H_2S) confirming CH_4 as the dominant component of the room T vapor phase. In three cases the P estimates agreed within error (±5 bars for MT, ±25 bars for LRS), but in the rest, the P determined from MT was consistently lower than that from LRS (mean discrepancy for all data = 33 ± 19 bars). This difference in P estimates is small when the errors on the measurements are considered. Two possible explanations for the discrepancy are that (1) the presence of other gases in the inclusions significantly affects the calculated CH_4 isochores or (2) the presence of clathrate in the inclusions at Th CH_4 affects the determination of the CH_4 densities. The presence of small amounts of additional gases is indicated in other inclusions in the tourmaline by the elevation of the critical point for CH_4 (~2 mol % CO_2 in the CH_4 phase would account for the observed c.p.). CO_2, N_2 and H_2S were searched for using LRS, which has the advantage of being an inclusion-specific technique. However, the small size and radius of curvature of these tube-shaped inclusions (1-2 μm diameter) raised the detection limit for individual gases above the usual 1 bar partial P (Pasteris et al., 1988, Geochim. Cosmochim Acta, 52, 979-988). Due to the necessary correction for atmospheric N_2, the elevation in detection limit was greatest for this gas at about 20 mol % (30 bars partial P). Under such conditions these gases could not be detected. The inclusions were therefore analyzed by gas chromatography using the method and equipment described by Bray and Spooner (this volume). Although GC gives a bulk analysis of all the inclusions in a sample, it does offer improved detection limits and, since the tourmalines contain only one visible generation of inclusions, a P signature was expected. The bulk composition (mol %) obtained by GC (2 g of sample) is 97.41% H_2O, 1.90% CH_4, 0.54% CO_2, 942 ppm N_2, 390 ppm C_2H_6, 70 ppm C_3H_8, 50 ppm C_2H_4, 30 ppm C_4H_{10}, 3 ppm C_3H_6 and 5 ppm C_4H_8. In addition to detecting a number of previously unsuspected trace species, the results confirm $CH_4 > CO_2$, indicating that we were successful in obtaining an analysis dominated by P inclusions. However, the amount of CO_2 is higher in the GC analysis than that indicated by MT. It is possible that the sample was contaminated by small amounts of pegmatitic quartz containing H_2O-CO_2 inclusions since small amounts of quartz were found amongst the crushed fragments of the tourmaline. (Authors' abstract)

See also Fluid Inclusion Research,v. 20, p. 379-380. (E.R.)

THOMAS, R., STRAUCH, G., BIELICKI, K.-H., HAASE, G., KAEMPF, H. and KLEMM, W., 1989, Temperature-time-matter related convection model of a granitic intrusion: 5th Working Meeting Isotopes in Nature, Leipzig, Sept. 1989, Proceedings, pt. 1, p. 397-409.

The covered granitic intrusion massif Eichigt-Schoenbrunn and the fluorite mineralization in the SW-Vogtland area are genetically closely connected. This follows from results of complex investigations by thermometry on different positions of depth, radiogeochronology from galena, adularia (Pb/Pb) and whole rock (Rb/Sr) as well as by isotope and geochemical elemental investigations. A two-stage convection model is presented: *First stage* (295...280 Ma): occurrence of a convection system closely connected to the granite forming a granitic high-T mineralization after intrusion finished at 3.6 km depth (paleosurface). *Second stage* (255...240 Ma): significant increase of the convection system by higher migration capacity of different hydrothermal fluids. The main granite-induced fluorite mineralization was formed by mixing of F-bearing NaCl—with crustal $CaCl_2$—fluids (δ^2H_{incl} 0...-50‰). (Authors' abstract)

Th measurements on quartz, garnet, calcite, cassiterite, sphalerite, paradoxite [i.e., adularia], fluorite, and barite. Silicate melt inclusions in quartz have Th 688 ± 10°C; some skarn garnet ≥510°C; all other inclusions

≤455°C. Some Th = 455 ± 9°C inclusions in quartz have dm halite, sylvite, and bischofite. The isotopic studies include H, O, Pb, Sr, and Rb. (E.R.)

TILLEY, B.J. and **LONGSTAFFE, F.J.**, 1989, Diagenesis and isotopic evolution of porewaters in the Alberta Deep Basin: The Falher Member and Cadomin Formation: Geochim. Cosmochim. Acta., v. 53, p. 2529-2546. First author at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

Diagenesis and porewater evolution in the Alberta Deep Basin have been studied by combining results from petrologic, stable isotope, and FI analyses of diagenetic minerals. Four stages of diagenesis and porewater evolution, corresponding to burial and subsequent uplift and erosion, have been identified. (From authors' abstract by E.R.)

TILLEY, B.J., NESBITT, B.E. and **LONGSTAFFE, F.J.**, 1989, Thermal history of Alberta Deep Basin: Comparative study of fluid inclusion and vitrinite reflectance data: Am. Assoc. petrol. Geol. Bull., v. 73, no. 10, p. 1206-1222. First author at Dept. Geology, Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

The thermal history of the Alberta Deep Basin, the gas-saturated westernmost part of the Western Canadian sedimentary basin, has been studied by analyzing aqueous and hydrocarbon FI in diagenetic cements and comparing the results with coal maturity data. Results indicate that most of the diagenetic quartz druse precipitated from low-salinity fluids (2-3 wt %) at 170-195°C. Calcite cement precipitated after quartz druse during uplift and cooling at 108-169°C. I rich in larger hydrocarbon molecules occur in cements that precipitated at 150°C, whereas CH_4-rich I occur in cements that precipitated at 165°C or at lower T after significant uplift and cooling of the basin.

Maximum burial T (Tmb), calculated from vitrinite reflectance data using the Lopatin-Waples TTI-R_o calibration, are significantly lower (150°C) than the T at which quartz druse precipitated in the same area (190°C). An equation directly relating Tmb and R_o, proposed by Barker and Pawlewicz in 1986, yields maximum burial T (200-210°C) only slightly higher than the fluid T. The results from this study suggest that hot fluids migrated updip along permeable conglomerates and bedding-plane fractures to produce unexpectedly high geothermal gradients (~38°C/km) in the western part of the study area. The apparent restriction of hot fluids to the western part of the study area suggests that convective heat transfer by fluids may have operated on a scale of only tens of kilometers in Lower Cretaceous rocks of the Alberta Deep Basin. (Authors' abstract)

TINGLE, T.N. and **AINES, R.D.**, 1988, Beta track autoradiography and infrared spectroscopy bearing on the solubility of CO_2 in albite melt at 2 GPa and 1450°C: Contrib. Mineral. Petrol., v. 100, p. 222-225.

TINGLE, T.N. and **BECKER, C.H.**, 1989, Photoionization time-of-flight mass spectrometry of organic compounds from mantle minerals: Presented at the 37th ASMS Conference on Mass Spectrometry and Allied Topics, May 21-26, Miami Beach, FL.

TINGLE, T.N., GREEN, H.W. and **FINNERTY, A.A.**, 1988, Experiments and observations bearing on the solubility and diffusivity of carbon in olivine: J. Geophys. Res., v. 93, no. B12, p. 15,289-15,304.

TINGLE, T.N., HOCHELLA, M.F., MATHEZ, E.A., BECKER, C.H. and **MALHOTRA, R.**, 1989, Constraints on the origin of organic compounds on crack surfaces in mantle xenoliths (abst.): Eos, v. 70, p. 1411.

TISCHENDORF, G., editor, 1989, Silicic Magmatism and Metallogenesis of the Erzgebirge: Central Institute for Physics of the Earth, VEB Geological Research and Exploration Freiberg, no. 107, Potsdam, 316 pp.

An extensive review (nearly 600 references) covering various studies of Sn-W-Cu deposits such as Altenberg, Ehrenfriedersdorf, Eibenstock, Schönbrunn, and Flöha; related Pb-Zn-Ag deposits; and possibly related Ba-F deposits, and including results from the pertinent fluid inclusion literature. See particularly pp. 221-242. (E.R.)

TOMSON, I.N., POLYAKOVA, O.P. and POLOHOV, V.P., 1989, Graphite-ilmenite mineralization in tin deposits—an indicator of mantle gas jets (Primorie region, USSR): Global Tectonics and Metallogeny, v. 3, no. 2-3, p. 101-xyz.

TORGERSEN, T., KENNEDY, B.M., HIYAGON, H., CHIOU, K.Y., REYNOLDS, J.H. and **CLARKE, W.B.,** 1989, Argon accumulation and the crustal degassing flux of ^{40}Ar in the Great Artesian Basin, Australia: Earth Planet. Sci. Lett., v. 92, p. 43-56. First author at Dept. Marine Sciences, Univ. Connecticut, Groton, CT 06340.

Measurements of the $^{40}Ar/^{36}Ar$ ratio of dissolved argon from groundwaters in the Great Artesian Basin, Australia, indicate the accumulation of significant radiogenic ^{40}Ar. This radiogenic ^{40}Ar cannot be supplied by in situ production or by dissolution. The magnitude of the radiogenic ^{40}Ar requires a crustal degassing flux of ^{40}Ar to be entering the aquifer. Within the errors of the data and assumptions regarding the composition and structure of the eastern Australian continental crust, this degassing flux approaches and may be equivalent to the whole crustal production of ^{40}Ar. A flux of this magnitude is in agreement with ^{40}Ar degassing estimates derived from atmospheric models. These measurements constitute the first direct measure of the ^{40}Ar continental degassing flux.

The distribution of radiogenic ^{40}Ar from crustal degassing in the aquifer is discontinuous with time, distance, and ^{4}He. This suggests that the crustal degassing processes for ^{40}Ar and ^{4}He are local, time dependent, and decoupled. This further suggests that the crustal degassing process may be tectonically and hydraulically linked with other continental-scale fluid processes. (From authors' abstract by E.R.)

TORIUMI, Mitsuhiro, 1989, Microstructures of regional and metamorphic rocks, *in* Shun-ichiro Karato and Mitsuhiro Toriumi, eds., Rheology of solids of the Earth: Univ. Minn., Dept. Geology and Geophysics, Minneapolis, MN, p. 319-337.

Indexed under FI. (E.R.)

TORNOS, F. and **LOCUTURA, J.,** 1989a, Fluid inclusion and geochemical evidence for fluid mixing in the genesis of Ba-F (Pb, Zn) lodes of the Spanish central system (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 89. Authors at Inst. Geol. y Minero de Espana, Rios Rosas, 23. 28003 Madrid, Spain.

Ba-F (Pb-Zn) hydrothermal mineralizations of the Spanish central system are developed along WNW-ESE trending dextral shears and extensional strike-faults within late-Hercynian adamellites. Mineralization shows a clear vertical and lateral zonation; in the deeper and external zones of the lodes fluorite is widespread, while in the upper and inner zones, barite is dominant.

FI and geochemical data suggest that such zonation can be explained by the mixing of hot (>250°C), hypersaline CO_2 poor ($X(CO_2)$ <0.05) deep fluids (epithermal fluids s.1.) and cool (<130°C), oxidized, more saline (>12 wt % NaCl eq.) CO_2-poor brines of sub-surface origin. Ore minerals were precipitated at relative low P (P(lith) = 170-500 b., P(hydrost) = 50-110 b.) and T (from 270 to 100°C) in a regime near the q-ms-fk and py-hm-mt buffers at progressively more alkaline pH.

In more reduced and acid conditions, such as those predicted for the deep zones of hydrothermal systems, fluids can carry up to some tens of ppm of Zn, Pb and Cu, mainly as chloride complexes. Such base metals, as well as F and part of the Ba, are thought to have been incorporated in the fluid due to hydrothermal alteration of the enclosing adamellites. While boiling seems quite an inefficient mechanism for ore deposition, oxidation and cooling destabilize metal complexes, causing deposition of Zn, Pb and Cu carried in solution. Increase in fO_2 produces ΣH_2S oxidation to SO_4^{2-}, giving rise to barite formation; fluorite deposition seems to be related to an increase in $a(Ca^{2+})/a(Mg^{2+})$ and cooling of the solutions.

We propose a genetic model for the mineralization related to fluid mixing in shallow and low T hydrothermal systems associated with late-Hercynian extension of Permo-Triassic age. Such an hypothesis is similar to those proposed for several Ba-F deposits of the European Hercynian Belt. (Authors' abstract)

TORNOS, Fernando and **LOCUTURA, Juan,** 1989b, Epithermal mineralizations of Hg in Ossa Morena (Usagre, Badajoz [Spain]): Bóletin de la Sociedad Española de Mineralogía, v. 12, p. 363-374. Authors at I.G.M.E. Rios Rosas 23, 28003 Madrid, Spain.

Usagre Hg-(Ba-Pb-Zn-Cu-Sb-As-Au) mineralization is linked with an epigenetic silicification of Lower Cambrian limestones along high angle tensional faults of late Hercynian age; those faults are also channelways for subvolcanic acid and basic igneous rocks. Such relationships allow classification of the mineralization as of "carbonate hosted" epithermal type; it shows some specific characteristics such as high Hg, Ba and base metal grades, low Sb content, pervasive silicification and high T of formation (300-350°C). Those features are probably associated with the deep environment of formation and the spacial relationship with stratiform mineralizations of barite with little cinnabar that outcrop in the area. Ore precipitation seems to be linked with oxidation, cooling or reaction with limestones of acid, saline (19-24% NaCl eq.) and CO_2-poor solutions. Paragenesis with Hg or Ba-Pb can be explained on the basis of local dominance of one mechanism over the others. (Authors' abstract)

TOURAY, J.C., 1989, Fluid inclusion studies and modelisation of the genesis of Mississippi Valley type ore-deposits: Chron. rech. min., no. 495, p. 21-30 (in French, English abstract). Author at Lab. Métall. et Géochim. minér., U.S. CNRS, Univ. Orléans, 45067 Orleans, France.

Fluid inclusions (F.I.) in transparent minerals (fluorite, barite, sphalerite, carbonates, quartz) from M.V.T. and related ore deposits have been characterized since the early fifties by microthermometry and microanalysis. On the basis of T, salinity, Ca/Na ratio and the usual presence of trapped hydrocarbons, inclusion fluids have been classically compared to oil-field brines.

Fluid inclusion studies may back up the thesis of ore precipitation by cooling of a single solution or conversely help to understand mixing processes between "normal" connate solutions (or brines derived from the dissolution of deep-seated evaporites) with hydrothermal fluids equilibrated at depth within the basement. Hydrodynamic modelling of the genesis of M.V.T. deposits involves either vertical fluid displacements or long range horizontal migrations of metalliferous brines. Both processes may be recognized from F.I. data, amongst other arguments, as illustrated on the western passive continental margin of the Tethyan basin. (From author's abstract by E.R.)

TOURAY, J.C., BENY, C., COELHO, C. and **DARDENNE, M.,** 1989, Fluid and solid inclusions in topaz and beryl from Goias, Brazil: A Raman microprobe investigation (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 90. Authors at Univ. Orl*ans, France.

Topaz and beryl crystals have been collected from the outer zone of the "Manchao Velho" pegmatite, Serra de Mesa (Goias, Brazil). P FI (CO_2-H_2O system) and trapped microphases in beryl and topaz have been investigated by Raman microprobe analysis. In the fluid fraction, only CO_2 has been detected; amongst the dp a small rhombohedral-shaped carbonate phase gave Raman peaks identical to those given by a reference rhodochrosite sample.

The solids trapped in topaz have been identified as quartz, a dioctahedral mica (possibly muscovite), albite and impure rutile; in beryl they are quartz, a dioctahedral mica and an unidentified spinel (possibly hercynite group).

Apparently, topaz formed simultaneously with a mica and albite (automorphic crystals) in a SiO_2-poor fluid (etched quartz grains) in contrast to beryl. Both minerals crystallized from a CO_2-rich aqueous system containing significant amounts of dissolved Mn. (Authors' abstract)

TOURAY, J.C. and **BOUCHOT, V.,** 1989, The Le Bourneix gold deposit (Central France) (abst.): Geol. Soc. London Min. Dept. Study Group Mtg., Univ. Wales, 1989, Abstracts, p. 7. First author at E.S.E.M., Université d'Orléans, 45067 Orleans Cedex, France.

The Le Bourneix Au deposit [is one of many in the St. Yrieix district] in the French Massif Central in the Limousin Hercynian basement. The economic mineralization (arsenopyrite, Au, pyrite, galena and Pb-sulfosalts) impregnates microsaccharoidal quartz resulting from cataclasis of initially barren vein-quartz. A later paragenesis associated with hyaline quartz comprises Ag-rich Au, sphalerite, galena, tetrahedrite and sulfosalts. Arsenopyrites have a range of compositions, with a mean As content equivalent to an "equilibrium T with pyrite," of about 400 ± 50°C. Hydrothermal alterations synchronous with ore deposition resulted in a phengite + chlorite association, then a propylitic chlorite + carbonate assemblage.

From fluid inclusion studies, it appears that the general evolution of the hydrothermal fluids is as follows: (a) circulation under high P (2 kb?) at 400 ± 50°C of a poorly saline solution with minor volatile contents; (b) mixing of this solution with a CO_2-rich vapor producing a heterogeneous fluid at 320°C, after a drop in P down to 0.6 kb; and (c) circulation of volatile-free aqueous solutions at decreasing T (300 to 120°C). Most of the economic ore probably formed at the transition from (a) to (b).

Lead isotopic data suggest a local source for metals, with mixing of poorly radiogenic lead from the basement orthogneiss with radiogenic lead from a supracrustal source. (From authors' abstract by E.R.)

TOURAY, J.C., MARCOUX, Eric, HUBERT, Pascal and PROUST, Dominique, 1989, Hydrothermal processes and ore-forming fluids in the Le Bourneix gold deposit, central France: Econ. Geol., v. 84, p. 1328-1339. First author at Ecole Supérieure de l'Energie et des Matériaux, Université d'Orléans, 45067 Orléans, Cedex 2, France.

The Le Bourneix Au deposit in the French Massif Central occurs within a shear zone in gneisses of the Limousin Hercynian basement. Au-bearing quartz lenses formed during extension phases, after cataclasis of initially barren quartz postdating mylonites (Bouchot et al., 1989). The economic mineralization (arsenopyrite, Au, pyrite, galena, and Pb-sulfosalts), hosted by microsaccharoidal quartz, formed after crystallization of arsenopyrite and pyrite, synchronous with white milky quartz. A later paragenesis associated with hyaline quartz comprises Ag-rich gold, sphalerite, galena, tetrahedrite, and sulfosalts. Arsenopyrites have a range of compositions, with a mean As content equivalent to an equilibrium T with pyrite, of ~400° ± 30°C. Hydrothermal alterations synchronous with ore deposition resulted in a phengite + chlorite association, and then a propylitic chlorite + carbonate assemblage.

From fluid inclusion studies, it appears that the general evolution of the ore fluids is (1) circulation under high P (2 kbars?) at 400° ± 50°C of a low-salinity solution with minor volatile contents, (2) mixing of this solution with a CO_2-rich vapor induced by a drop in P down to 0.6 kbars producing a heterogeneous fluid at 320°C, and (3) circulation of volatile-free aqueous solutions at decreasing T (300°-120°C) and salinity.

Most of the economic ore probably formed at the transition from (1) to (2). Lead isotope data suggest a local source for metals, with mixing of poorly radiogenic lead from the basement orthogneiss with radiogenic lead from a supracrustal source. (Authors' abstract)

TOURET, J.L.R., 1989a, Free CO_2 and fluid-absent domains in lower crust: Model based on fluid inclusion studies (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-248. Author at Free Univ., Amsterdam, The Netherlands. [Paper not presented at Congress. E.R.]

Many lower crustal granulites contain early fluid inclusions that fall basically into two categories: high-density CO_2 and NaCl-rich brines. Other components, such as N_2 and CH_4, seem also to occur in some high P granulites (Calabria, Italy, Massif Central, France), but their role needs to be further substantiated. Many inclusions have been trapped or reequilibrated during post-peak metamorphic conditions, but estimating that all inclusions are late is at odds with some fundamental observations:

1. Some fluids, notably brines, are related to specific lithologies (metasediments, acid volcanics) and they have been inherited from a supracrustal premetamorphic stage (Touret, 1985). This does not mean that they witness the existence of a permanent free fluid phase, but they indicate that some inclusions, at least, were not completely obliterated during high-grade metamorphic recrystallization.

2. Some granulites, notably from India, Southern Norway, Brazil, etc., contain many more CO_2 inclusions than any other comparable sample from another metamorphic grade. Some of these inclusions, which occur not only in quartz, but also in garnet, pyroxenes, feldspars, etc., are demonstrably trapped under peak metamorphic conditions (Touret and Hansteen, 1988). Their occurrence indicates a local influx of CO_2 during peak metamorphic conditions and the existence, at this emplacement, of a free synmetamorphic CO_2-rich fluid phase. A number of arguments plead in favor of a deep-seated, mantle-derived origin for the CO_2 and its magmatic transportation in the lower crust by CO_2-saturated synmetamorphic intrusives (Frost and Frost, 1987). At the magmatic source, the CO_2 was either already gaseous and dissolved in the magma or possibly combined in the form of Mg/Fe-rich carbonates or eventually carbides. It must be noted that at the T which prevailed during the CO_2 liberation in the lower crust (about 1000°C), the O fugacity imposed by mineral assemblages is compatible with the existence of graphite. Local CO_2 streaming, which remains limited to the immediate vicinity of the synmetamorphic intrusions, will therefore not lead to any graphite precipitation. A rapid decrease of fO_2 during cooling may eventually lead to the reduction of some CO_2 into graphite, as actually seen in some inclusions.

Many CO_2 inclusions are trapped or reequilibrated after peak metamorphic conditions. The evolution of their density, compared to P-T conditions recorded in neighboring mineral assemblages, constrain possible postmetamorphic P-T trajectories between the lower crust and the surface. Granulites originating below 30 km (high-P granulites) are characterized by a constant, regular decrease of both P and T ('pseudo-isochoric P-T path"). For the other types, notably for the low-P granulites (depth of formation ~15 km), a period of isobaric cooling (between roughly 900°C and 500°C) is then followed by a rapid uplift at more or less constant T. This complicated type of P-T path has been documented in various regions from different ages, and it seems to characterize many Archean and Proterozoic granulites.

These observations support a model in which vapor-absent and CO_2-dominated domains may coexist in time and space. Refinements of this model require: (1) a better understanding of fluid transfer between lower crust and upper mantle in continental environments; (2) more information about the role and origin of nitrogen; and (3) some knowledge of the timing of fluid pulses during and after peak metamorphic conditions. (Authors' abstract)

TOURET, J.L.R., 1989b, Fluid control in the lower crust: Niedersächsische Akademie der Geowissenschaften, Publikation Heft 1, Gesteinfluide, p. 57-68 (in English). Author at Inst. Earth Sciences, Free Univ., de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

Granulites are major constituents of the lower crust. After a brief recall of some petrological and geochemical characteristics of granulites, the currently two most favoured granulite models ("vapor absent" versus "carbonic metamorphism") are presented and discussed. FI data suggest a local abundance of CO_2 during and after peak metamorphism, but other fluids (brines) may be present in specific lithological environment. In many respects, both models are complementary rather than opposite. Fluid-absent and fluid-abundant domains may both occur in the lower crust, at a scale yet unknown but potentially determinable by detailed studies on favorable samples. (Author's abstract)

TOURET, J.L.R. and **BURKE, E.A.J.**, 1988, Fluid phases in minerals: GEA, Stichting Geologische Aktiviteiten, v. 21, no. 3, p. 61-70 (in Dutch).

A review with 26 excellent black and white photomicrographs (and a striking color photograph on the cover), particularly of daughter minerals. (E.R.)

TÖRÖK, Kálmán, 1989, Fluid inclusion study of the gneiss from the borehole Nagyatád K-1, 11, SW Transdanubia [Hungary]: Acta Mineral.-Petrogr., Szeged, v. XXX, p. 115-126. Author at Dept. Petrology and Geochemistry, L. Eötvös Univ.

FI in synkinematic quartz lenses, segregations and those in the matrix quartz were studied from the 11th core of the Nagyàtád-K-1 borehole. This one is bored in the Somogy-Dráva Basin, SW Hungary. It explored a polymetamorphic staurolite-kyanite-garnet gneiss mass. The studied FI can be divided into three groups according to their composition: (1) H_2O +1.7-14.3 NaCl eq. wt % salt, (2) CO_2 +/- CH_4 and/or N_2 [$X(CH_4\text{-}N_2) \leq 0.1$], (3) mixed CH_4-N_2-CO_2.

The peak P-T conditions of two metamorphic phases were inferred from geothermobarometric data of Arkai (1984) and the obtained FI data. The inferred P-T conditions of the first metamorphic phase were ~890-900 MPa and 550°C. The fluid, existed at these P-T conditions, was a CO_2-rich one. The maximum P and T, reached during the second stage of metamorphism, was determined by the method of intersecting isochores of two immiscible fluids, trapped simultaneously. On the basis of this method the obtained P was 240-260 MPa and the T ~540°C. All three compositional types were present during the second metamorphic event. The third metamorphic stage was a very low-low grade one with a simple, dilute aqueous solution. (From author's abstract)

TROFIMOV, N.N., RYCHKOV, A.I. and **D'YAKONOV, V.V.**, 1989, Iodine as an indicator of concealed porphyry-copper mineralization in Kazakhstan: Geologiya i razvedka, 1989, no. 8, p. 57-62 (in Russian; translated in Int'l Geol. Rev., v. 31, p. 1063-1067). Authors at Lumumba Univ., Moscow, U.S.S.R.

The authors find that where deposits are overlain by thick surficial sediments, highly mobile iodine is a better indicator of mineralization than the metallic elements more commonly used in geochemical exploration. (Authors' abstract)

TRUFANOV, V.N., 1988, Thermobarogeochemical criteria of mineral formation and ore genesis from boiling solutions: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 5-6 (in Russian). Author at Rostov State Univ., Rostov-on-Don, U.S.S.R.

A discussion of boiling phenomena in natural solutions, indicating that fluid inclusions yield the following criteria for boiling: (1) direct observations of boiling on heating and cooling of gas-liquid inclusions [sic], (2) presence of coeval fluid inclusions of various degrees of filling, homogenizing at the same temperature, (3) polymodal decrepitation effects of the thermovacuum curves of gas release [sic; A.K.]. (A.K.)

TSAY, S.V., GILYAROV, V.N., ZAREMBO, V.I. and **PUCHKOV, L.V.,** 1988, Bulk properties of aqueous calcium chloride at high state parameters: Geokhimiya, no. 7, p. 968-972, 1988 (in Russian, translated in Geochem. Int'l, v. 26, no. 2, p. 52-56, 1989). Authors at Leningrad Technological Inst., U.S.S.R.

PVTX measurements have been made on dilute Ca chloride solutions at 398-573 K and 10-80 MPa. A method is described for calibrating the constant-volume and piezometer from a single standard liquid. The T and P coefficients are considered for the apparent molar volume of Ca chloride in aqueous solution. (Authors' abstract)

TUFAR, W., GIEB, J., SCHMIDT, R., MÖLLER, P., PÖHL, W., RIEDLER, H. and **OLSACHER, A.,** 1989, Formation of magnesite in the Radenthein (Carinthia/Austria) type locality: Monograph Series on Mineral Deposits No. 28, p. 135-171, Berlin-Stuttgart, Gebrüder Borntraeger.

The Radenthein deposit represents the type locality for a sparry magnesite mineralization which is characterized by its occurrence in a series of the crystalline basement. The stratiform magnesite layer (magnesite bed) is part of a thick, strongly metamorphically overprinted sequence. The magnesite layer and its wall rock series have both been subject to an identical succession of tectonic events and metamorphosing processes. Today, the magnesitic marble displays, in accordance with its mode of formation and subsequent overprinting, specific contents of trace elements, positive Eu-anomalies, slightly negative $\delta^{13}C$ values relative to PDB, and a high degree of scattering of $\delta^{18}O$ values. Revealing also are fluid inclusions in magnesite [p. 159-161], exhibiting several maxima in Th. (From authors' abstract by E.R.)

TULLIS, Jan and **YUND, R.A.,** 1989, Hydrolytic weakening of quartz aggregates: The effects of water and pressure on recovery: Geophys. Res. Lett., v. 16, no. 11, p. 1343-1346. Authors at Dept. Geological Sciences, Brown Univ., Providence, RI 02912.

In order to test the effect of "water" at high P on the rate of dislocation climb in quartz, we have performed annealing experiments on portions of a quartzite sample previously deformed at 700°C, 10^{-5} sec^{-1}, and 1500 MPa which had a high dislocation density but few subgrain boundaries. Portions of the deformed sample were annealed at 1500 MPa and 800°C for 1 and 4 days; samples with 0.17 wt % H_2O added have a lower average dislocation density and a greater number of subgrain boundaries than those without H_2O added. Annealing at 800°C for 4 days at 1500 MPa after vacuum drying at 800°C, or at 550 MPa with 1.17 wt % H_2O added, produces no significant change in the dislocation microstructure. These results indicate that: (1) the presence of a H_2O-related defect in quartz accomplishes hydrolytic weakening by making the climb of dislocations easier, thus increasing the rate of recovery at a given imposed strain rate, and (2) for laboratory times this weakening requires a $P > 550$ MPa. (Authors' abstract)

TURNER, G. and **BURGESS, R.,** 1989, Volatile-rich fluids in diamonds: Lunar and Planet. Sci., v. 20, p. 1140-1141.

URAI, J.L., 1989, High temperature deformation of wet and dry Carrara marble (abst.): Eos, v. 70, p. 1380. Author at Instituut voor Aardwetenschappen, P.O. Box 80021, 3508 TA Utrecht, Netherlands.

Carrara marble samples were deformed to strains of up to 20% at T between 600 and 1000°C and strain rates of around 10^{-5} s^{-1} using the Paterson gas apparatus at ANU Canberra. Samples were jacketed in sealed Pt capsules, with or without the addition of up to 2 wt % H_2O. Weight loss tests after the wet experiments confirmed that H_2O was retained in the jackets during the runs. Microstructural development was investigated by light microscopy and by SEM of split grain boundaries.

All samples showed behaviour in agreement with Schmid et al. (1980)'s results, with recrystallized grains developing >700°C by both subgrain rotation and high angle grain boundary migration. At the highest T samples underwent rapid dynamic grain growth. The wet samples recrystallized at comparable rates to dry ones, developing essentially the same microstructures under otherwise identical conditions. Grain boundaries in the wet samples had an island structure consisting of essentially dry, I-free regions and isolated or locally semi-continuous FI, which could locally have film-like morphologies. These FI are interpreted to interact with migrating grain boundaries, thereby changing in morphology and position, sometimes being left behind as FI in the new grains. Even during dynamic recrystallization the fluid does not form an interconnected network, in agreement with recent work on statically equilibrated wet marbles. These microstructures indicate that in a marble deforming under high grade metamorphic conditions, permeabilities for a H_2O-rich fluid will be low, due to the "self-sealing" nature of any interconnected, fluid filled porosity.

Fluid-containing grain boundaries during dynamic recrystallization are proposed to have a range of possible morphologies characterised by two end members, one of which is the marble behaviour described above, and the other the case of wet rock salt where the fluid forms interconnected networks of films during migration. The behaviour displayed by a given mineral will be determined by factors such as equilibrium wetting angle, the kinetics of necking down- and of the film-maintaining processes, and by grain boundary migration rates. (Author's abstract)

UZUNLAR, N., PATERSON, C.J., NELSON, G. and **LONGSTAFFE, F.J.,** 1989, Tertiary epithermal to mesothermal Au-Ag mineralization in the Homestake Mine, Lead, South Dakota: A magmatic origin (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A350. First author at Dept. Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, MO 57701.

Epithermal to mesothermal Au-Ag deposits in the northern Black Hills are associated with an east-west zone of Tertiary (40-60 m.y.) alkalic intrusions. Lithologies include monzonites, quartz monzonites, trachytes, quartz trachytes, rhyolites, latites and phonolites.

Apart from the Precambrian iron formation-hosted Homestake Au deposit, epithermal Au-Ag veins occur in the Homestake Mine and are related to Tertiary trachytic porphyries. The vein system extends at least to 3 km depth and shows vertical and lateral zoning with respect to intrusions. The veins assemblages vary from quartz + pyrite + anhydrite + biotite + rutile + molybdenite + cosalite in the inner zone to quartz + adularia + pyrite + galena + sphalerite in the middle zone to calcite + pyrite + siderite in the outer zone. Au grades increase outwards and Ag shows high concentrations in the middle zone.

Fluid inclusions have low salinities (<10 wt %), and Th are 350-400°C in the inner zone, 300-350°C in the middle zone, and <300°C in the outer zone. CO_2-bearing fluids occur in the inner zone. $\delta^{18}O$ and δD values of the fluids are 6.2 to 11.6 and -53 to -75‰, respectively. The isotopic and fluid inclusion data, and metal and mineral zoning, suggest a magmatic origin for the ore-forming fluid. (Authors' abstract)

VALASIS, A. and **PASAL'SKAYA, L.F.,** 1987, Fluid component of salic minerals of formation-related petrological types of the Korsun-Novomirgorod pluton (USSR): Dokl. Akad. Nauk Ukr. SSR, Ser. B, Geol., Khim. Biol. Nauki 1987, (12) p. 6-9 (in Russian).

The H_2, CH_4, CO, and CO_2 concns. of feldspars and quartz from the Korsun-Novomirgorod pluton (KMP, of the Ukrainian Shield, USSR) were detd. by chromatog. of gases sepd. during heating at 1170 K in a He atm. under P. In addn., the H_2O concn. of vacuoles in these minerals was detd. by NMR. The anorthosites, pegmatites, and syenites of the KMP, which is a typical anorthosite-rapakivi massif, are less satd. with gases than are the granites. This relation contradicts the idea that the granitic rocks and gabbro-anorthosites were derived from products of the same magma chamber, through magmatic differentiation. The pegmatites and syenites of the KMP formed at zones of contact with granitic rocks and gabbro-anorthosites; apparently inversion of the fluid regime occurred in contact zones.

Pegmatite-bearing granites formed from the alternation of rapakivi by reducing fluids. Difference in fluid regime accounts for the formation of the various types of pegmatites found in the KMP). (CA 110:234771u)

VALUEV, O.V. and **MAKARYUKHA, S.V.**, 1988, Certain signs and reasons for solutions boiling and prognosis of the favorable ore precipitation conditions of the Subashi deposit: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 27-28 (in Russian). Authors at Rostov State Univ., Rostov-on-Don, U.S.S.R.

Subashi deposit belongs to the scheelite-sulfide-skarn type. Ore bodies occur in graphite-amphibole-biotite schist complexes, and five stages of ore mineralization can be distinguished: (1) progressive metamorphism, (2) garnet-wollastonite-zoisite skarns, (3) ferrosalite-clinozoisite-vesuvianite stage of the post-skarn metasomatites, (4) albite-zoisite-amphibole-epidote-scheelite stage of the post-skarn metasomatites, (5) sulfide-chlorite-carbonate-quartz stage. W ores are connected with intrusions of Glavnyi Ridge.

Fluid inclusions in minerals of stage 3 (vesuvianite and clinozoisite) and stage 4 (scheelite) are filled essentially with gas (80-90%) or gas-liquid (30-70 vol % gas); sometimes vacuole walls have encrustations of solid phase. Quartz bears inclusions filled with gas, gas + liquid (+ trapped mineral) and liquid. The studied minerals contain inclusions: P (25%), PS (30%) and S (45%). Vacuum decrepitometry yielded two intervals of gas release: 70-340°C and 530-700°C. Chromatographic analysis of the released gases showed that H_2O prevails in the first interval (plus CO_2, CH_4, O_2, N_2) and CO_2 is the main component in the second interval. Boiling of the mineral-forming fluids occurred at stages 3 and 4 due to the solution T increase and additional dissolution of CO_2 from the decomposing carbonates. (From the authors' abstract, translated by A.K.)

VAN DUIN, J.A., 1989, The charnockitic igneous suite of the Turku region: Preliminary data (abst.): Geol. Surv. Finland Special Paper 8, p. 133. Author at Inst. Earth Sci., Vrije Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

The charnockitic igneous suite ranges from pyroxenite, gabbro, diorite, leuco-norite, and enderbite to charno-enderbite. The latter is closely associated with granite-trondhjemite. After intrusion of the suite, the area underwent several deformation phases and, most important, granulite facies metamorphism. T of 750-820°C and P of 4-6 kbar prevailed during peak metamorphic conditions. Even so, igneous features such as angular mafic enclaves and xenoliths are well preserved. Igneous-derived rocks were not extensively migmatized during the peak of metamorphism, and orthopyroxene-bearing mobilizates, in particular, have not been found. In these rocks, CO_2-rich inclusions are scarce or absent.

In the West Uusimaa complex, orthopyroxene-bearing tonalites occur within the boundaries of the granulite domain. These charnockites are migmatized, and orthopyroxene mobilizates are widespread. Large quantities of CO_2-rich inclusions are found throughout the area. The CO_2 is clearly associated with granulite facies metamorphism.

Both areas lie within the east-west orientated Svecofennic belt, and although PT conditions are comparable, they differ considerably in the activity of external fluids. The absence of orthopyroxene-bearing mobilizates, the small quantities of CO_2-rich inclusions, and the well-preserved igneous features indicate fluid-absent metamorphism for the Turku region. (From author's abstract by E.R.)

VAN HORN, Stephen and **JOESTEN, Raymond**, 1989, Calibration of P-T-X(CO_2) and fluid/rock ratio in the contact aureoles of basalt feeder dikes, Killala Bay, Ireland (abst.): Eos, v. 70, p. 494. Authors at Dept. Geol. and Geophysics, The Univ. Connecticut, Storrs, CT 06269-2045.

Alkali olivine basalt feeder dikes cutting limestone are characterized by the presence of one or more pairs of internal contacts that mark an abrupt change in grain size from coarse to fine coarse to fine on passing inward, recording one or more periods of intrusion of magma into the core of the partially solidified dike. Stratigraphic estimates of P at the time of intrusion lie in the range 25.5-68 MPa. Mineral assemblages in a 0.3 m bed of limestone vary with distance from the contact of a 5.3 m dike as follows:

>3.3 m	calcite + quartz + plagioclase	
2.9-0.8 m	calcite + quartz + plagioclase	+ grossular
<0.5 m	calcite +	+ grossular + wollastonite

Authigenic plagioclase of $AN_{<20}$ does not appear to be consumed in the initial garnet-forming reaction, which probably involved kaolinite (2.9-2.3 m) and illite (≤1.5 m). Apophyllite and APO + WO occupy large pores left on dissolution of echinoid plates (<1.5 m). Presence of the four-phase assemblage Cal + Qtz + Pl + Grs over the interval 0.8-2.9 m and gradual increase in the abundance of garnet ($GRS_{70}ADR_{30}$) over the interval 2.9-1.5 m is consistent with internal buffering of fluid composition. Sudden appearance of 20 vol % Wo at 0.8 m is consistent with its production at the Cal + Qtz + Pl + Grs + Wo isobaric invariant point, which has T, $X(CO_2)$ coordinates of 498°C, 0.45 at 25.5 MPa and 508°C, 0.24 @ 68 MPa for AN_{100} and GRS_{100}. Assuming an infiltrating fluid of pure H_2O, measured values of reaction progress (ε) are consistent with minimum volumetric H_2O fluid/rock ratios in the range 1.4-0.8 at the invariant point over the range of uncertainties in the estimate of lithostatic P. (Authors' abstract)

VANKO, D.A., 1989a, Fluids in oceanic layer 3: Preliminary fluid inclusion evidence from ODP Hole 735B, southwest Indian Ridge (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 67. Author at Dept. Geol., Georgia State Univ., Atlanta, GA 30303.

ODP Hole 735B was drilled directly into grabbroic ocean crust exposed along a transverse ridge at the Atlantis II Fracture Zone, southwest Indian Ridge. The transverse ridge, shoaling to 700 m below sea level, is located along the eastern margin of the N-S tending fracture zone. Magnetic lineations parallel to the slow-spreading southwest Indian Ridge imply a crustal age of about 12 million years. Complex lithostratigraphy within the 500.7 m hole was divided by the shipboard party into six distinct units: foliated metagabbro with development of mylonitic fabrics, olivine gabbro, olivine gabbro with portions of iron-titanium oxide, gabbro, magnetite-ilmenite gabbro, uniform olivine gabbro, and olivine gabbro with troctolite. Also encountered were several hydrothermal brecciated zones and small plagiogranites. Early high-T metamorphism resulted in foliation and mylonitization of gabbros in some intervals. Initial estimates indicate that these processes took place at greater than 600°C. Subsequent brittle alteration is evidenced by abundant small (millimeter-scale) veins, primarily filled with hornblende and sodic plagioclase. Other S alteration phases include epidote, prehnite, calcite, apatite, and diopside. Based on mineral assemblages, most of the veins appear to have formed under conditions similar to greenschist-grade metamorphism.

FI are abundant within both P and S phases. Calcic plagioclase contains early trails of multiphase aqueous inclusions, where dxls include halite and a birefringent phase. Distinct trails of vapor-rich inclusions in P plagioclase also occur. Vapor-rich inclusions are present in P quartz that occurs in a small granophyric interval. The fluids in P plagioclase and quartz expand on crushing owing to the presence of compressed gases. In many inclusions, clathrates form on freezing. Initial measurements of Tm clathrate vary from +1.6°C to over +20°C. Laser Raman determinations on several inclusions indicate the presence of CH_4, consistent with the high Tm clathrate.

Aqueous FI in secondary hornblende and plagioclase exhibit Tm ice at variable T, with many between -3°C and -0.5°C, but with a substantial proportion between -3°C and -10°C, and a population between -22°C and -25°C. Th range from ~150°C and 350°C with individual sample modes from 240°C to 270°C (metagabbro with inclusions in plagioclase and hornblende), and 340°C (granophyre).

Fluids trapped as inclusions in P minerals are probably largely magmatic, accounting for the observed compressed gas content. Fluids in S veins may be more likely to represent seawater-derived hydrothermal solutions. A major problem is to determine the relative proportions of magmatic and hydrothermal fluid participation in the metamorphic history of these oceanic layer 3 samples, and to integrate this information with other studies on Hole 735B that, together should lead to a detailed tectonic-magmatic-hydrothermal model for ocean crustal genesis at slow-spreading ridges. (Author's abstract)

VANKO, D.A., 1989b, Fluid in the oceanic crust: Evidence from fluid inclusions (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 68. Author at Dept. Geol., Georgia State Univ., Atlanta, GA 30303.

FI analysis provides information which complements that obtained by direct sampling of hot springs, experiments and modelling of seawater-basalt interaction, and analysis of volatile magmatic species. A broad understanding of mineralogic, petrologic, and tectonic controls on the types and amount of fluids present is needed in order to construct a comprehensive model for global geochemical cycling. A suitable model should include volatile reservoirs in the mantle, all major subdivisions of oceanic crust, and the hydrosphere. Processes controlling fluid fluxes include melting, magma ascent, volatile concentration by fractional crystallization, seawater interaction with ocean lithosphere, devolatilization during subduction, and arc magmatism, among many others. There is considerable potential for FI studies to contribute to knowledge about several of these reservoirs and processes.

Distinct sources for fluid in oceanic crust are magmatic volatiles and seawater. Hydrothermal seawater-derived fluids have been sampled at hot springs, however FI results are scant. Most FIs are noted in quartz veins within altered chlorite-rich basalts. The FIs have several modes of origin ranging from those in matrix quartz to P an S FIs in vein quartz. Gallinatti (1984, J. Geophys. Res., 89, 3275) and Delaney, et al. (1987, J. Geophys. Res., 92, 9175) measured Th of 300°C to 200°C, and up to 10 wt % NaCl eq. in greenstones from the Kane Fracture Zone (KFZ). Other KFZ rocks from a dredge haul yield similar results (unpub. data). Quartz in greenstones from the FAMOUS area (Mid-Atlantic Ridge) has FIs with Th ~230°C, 1.5-5.0 wt % NaCl eq.; and quartz-cemented breccia dredged from the Atlantis II FZ has Th modes at 240°C and 290°C, and 3-5 wt % NaCl eq. FIs in quartz-pyrite rocks dredged from a seamount have Th of 220°C and avg. 4 wt % NaCl eq. All of these aqueous FIs are interpreted as having a seawater origin.

Aqueous FIs in oceanic plutonic rocks are hosted by quartz, epidote, S plagioclase, and amphibole, among other vein minerals. Quartz veins at the Mathematician Ridge have FI evidence for hydrothermal phase separation at 600-700°C (Vanko, 1988, J. Geophys. Res., 93, 4595). Aqueous FIs in igneous minerals in KFZ gabbros include low-moderate salinity ones with Th of 400°C and 200-300°C (Kelley and Delaney, 1987, Earth Planet. Sci. Lett., 83, 53).

Magmatic volatiles from MORB include H_2O, CO_2, CO, CH_4, Cl, F and S (e.g., Byers, et al., 1986, Earth Planet. Sci. Lett., 79, 9). Many oceanic plutonic rocks have early FI trails in igneous minerals, and recent work on samples from the Atlantis II FZ shows that such FIs contain compressed gases (CH_4 has been confirmed using a laser Raman microprobe). FIs of possible magmatic origin were also described from KFZ gabbros, where Th was >700°C for FIs in P apatite that indicated phase separation (Kelley and Delaney, op cit). In both cases, the FZ setting is expected to promote extensive fractional crystallization according to recent tectono-magmatic models for ridge crest processes. (Author's abstract)

VANKO, D.A., MILBY, B.J. and HEINZQUITH, S.W., 1989, Massive sulfide dredged from a young East Pacific Rise flank seamount at 14°09'N: Petrographic, fluid inclusion, and trace element characteristics (abst.): Eos, v. 70, p. 494. Authors at Dept. Geol., Georgia State Univ., Atlanta, GA 30303.

Massive sulfide (MS) composed of pyrite (PYR) and quartz (QZ) was dredged with atacamite and Fe-oxides from the summit of a volcano located 14°09'N, 104°22'W about 15 km west of the EPR. The QZ has sparse P L-V FI with Tm (ice) = -2.4°C and Th = 216°C, σ = 35°C. This fluid is 4.0 wt % NaCl eq (seawater is 3.5 wt %) and trapping T is 240 ± 35°C. (From authors' abstract by E.R.)

VANKO, D.A. and STAKES, D.S., 1989, Petrology of alteration in oceanic layer 3, ODP Hole 735B, southwest Indian Ridge (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A329. First author at Dept. Geology, Georgia State Univ., Atlanta, GA 30303.

ODP Hole 735B is located adjacent to the Atlantis II Fracture Zone, SW Indian Ridge, on 12 m.y. old crust. 500 m of plutonic rocks were cored, and samples have been studied to determine the nature of hydrothermal alteration in oceanic layer 3. We have analyzed minerals (including O isotopes of mineral separates) and fluid inclusions.

The top 140 m (Units I and top of II) is metagabbro with plastic deformation and subsequent mm-scale veining normal to foliation. Veins are hornblende (hb) ± andesine. Minerals are slightly depleted in O18. Hb contains var. Cl up to 1.5 wt %. Fluid inclusions (flincs) in hb and andesine have var. salinity. This alteration occurred from 650-550°C, by seawater-derived fluid, at low W/R, during and after pervasive ductile deformation.

Below 140 m, the dominant alteration is in breccia zones and cm-scale plagioclase-diopside veins. Minerals are strongly O18-depleted, hb contains little Cl, diop has low non-quad components, and plag (oligoclase and albite) and diop both contain low-salinity fluid inclusions. This alteration occurred at 540-480°C, based on isotopic and Na-Ca exchange equilibria. Fluid was modified seawater, local W/R was high in the veins but low overall.

Combining flinc heating data with other thermometry, we obtain a P of 95-125 MPa for a sample at 347 m depth, placing the original depth at 2-3 km below the ridge crest seafloor. (Authors' abstract)

VASILENKO, V.N. and **USHAK, A.T.**, 1988, Role of solution boiling processes during formation of sulfide deposits: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 13-14 (in Russian). Authors at Rostov State Univ., Rostov-on-Don, U.S.S.R.

Mineralogical features and decrepitation used as evidences for boiling of mineral-forming solutions. (A.K.)

VAUGHAN, D.J., 1989, Spectroscopic studies of minerals: Principles, applications and advances: Mineral. Mag., v. 53, no. 370, p. 133.

An issue of this journal is devoted to such studies. (E.R.)

VAUGHAN, D.J., SWEENEY, M., FRIEDRICH, G., DIEDEL, R. and **HARANCZYK, C.**, 1989, The Kupferschiefer: An overview with an appraisal of the different types of mineralization: Econ. Geol., v. 84, p. 1003-1027. First author at Dept. Geology, The University, Manchester, M13 9PL, England.

The Kupferschiefer, a thin (<4 m) bed of marine bituminous marl of Upper Permian (Zechstein) age, occurs over a large area of north-central Europe and has, in certain areas, been exploited for silver and some base metals, notably copper, since medieval times. It has been regarded as the type example of a shale-hosted, strata-bound sulfide deposit and theories regarding the origins of Kupferschiefer mineralization have exerted considerable influence on theories of ore genesis.

Although large areas of the Kupferschiefer contain only average concentrations of base and precious metals compared to other shales and marls, in certain areas the concentrations reach ore grade. The ores in such regions contain sulfides of Cu, Pb, and Zn and may be enriched in a variety of other elements, notably V, Mo, U, Ag, As, Sb, Bi and Se; Cd, Tl, Au, Re, and the platinum-group metals are also reported; lateral and vertical zoning of Cu, Pb, and Zn may be observed; and in some areas, a reddening of the rocks adjacent to ores (Rote Fäule facies) is a useful exploration guide. The Kupferschiefer in Poland, in two contrasting regions in Germany (the Lower Rhine basin and the Hessian depression) and in England (where it is termed the Marl Slate) are compared and provide evidence for four types of mineralization.

The first (and oldest) is a weakly mineralized type exemplified by the English Marl Slate. Average base metal content of this type is ~100 ppm. Detailed mineralogical, geochemical, and isotopic studies indicate that the mineralization is synsedimentary; these studies have enabled a model to be developed in which precipitation of the various mineral phases can be related to stratification of the early Zechstein sea and oscillations in water and oxic-anoxic boundary levels.

The second is an average mineralization involving base metal content at the 2,000-ppm level. In this case, the study of German examples indicates the important influence of strata underlying the Kupferschiefer, as stressed by subdivision into a basin type that overlies thick Rotliegende sediments, and a schwellen type that overlies Paleozoic basement. The two subtypes differ in mineralogy and overall base metal ratios, indicating the importance of underlying strata as a source of metals. The relationship between Ba concentrations in the Kupferschiefer and barite mineralization in underlying rocks is also clear from geochemical (including Sr isotope) studies of German examples. The evidence points to an early diagenetic origin for the average mineralization, with sulfur derived bacteriogenically interacting with low-temperature solutions deriving metals largely from immediately underlying rocks.

The third is an ore mineralization where the average base metal concentration reaches ~3%. Zonation is clearly developed, as is the association of the Rote Fäule facies with mineralization, although the detailed zoning patterns are more complex than commonly believed. The ore mineralization type is generally restricted to the regions representing the margins of Rotliegende basins, and models of origin associated with late diagenetic processes and the introduction of metal-rich brines (possibly associated with basin compaction) are in line with the geologic and geochemical evidence. Preliminary fluid inclusion data on strata associated with the mineralization point to T of ~120°C, and organic maturation studies can also be used to support models involving introduction of oxidative metal-rich brines during late diagenesis. Again, sulfur isotope data point to fixation of the metals by sulfur derived from bacterial reduction of sulfate.

The fourth mineralization associated with the Kupferschiefer is a much later (postdiagenetic) structure-controlled mineralization (Rücken) involving Co, Ni, Ba, As, and Ag phases, genetically distinct from the types mentioned above and of probably hydrothermal origin. Other possible episodes of mineralization can be identified on a local scale; in many cases insufficient data are available to assess their genetic significance.

The Kupferschiefer is a deposit that appears to be the product of a variety of mineralizing processes influencing by the environment of deposition of the host rock and the underlying geology, but there are many unifying features; notably, that the bulk of the evidence still points to fixation of metals as sulfides by bacteriogenic processes. (From authors' abstract by E.R.)

VEKSLER, I.V. and **TEPTELEV, M.P.**, 1989, Phase equilibria in the system nepheline-diopside-sphene: Doklady Akad. Nauk SSSR, v. 309, no. 6, p. 1461-1464 (in Russian). Authors at Inst. Geochem. and Anal. Chem. of Acad. Sci. of USSR, Moscow, U.S.S.R.

The system was studied at 1300-1020°C (atmospheric pressure?—A.K.). Time of a run at lower temperature range was 100 hours, and 175 experimental points were obtained. Pertinent to Ti-rich ultramafic-alkaline melt inclusions. (A.K.)

VERGNIOLLE, S. and **JAUPART, C.**, 1989, Degassing in viscous liquid at constriction: New model for basaltic eruptions (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-294.

VIAU, C.A., AULSTEAD, K.L. ELIUK, L.S. and **KROUSE, H.R.**, 1989, The origin of H_2S and elemental sulphur in deep carbonate reservoirs in western Canada: Abstracts of Papers, Am. Chem. Soc., 197th Nat'l Meeting, Dallas, Texas, April 9-14 (unpaginated).

Light hydrocarbon gases can serve as agents for thermochemical sulphate reduction (TSR) in some carbonate reservoirs of western Canada (Nature, 333, 415-419, 1988). Petrographic observations show that dissolution of anhydrite, precipitation of elemental sulphur and calcite, calcitization of anhydrite as well as dissolution and reprecipitation of the dolomite itself are by-products and consequences of TSR. Unlike many documented instances, the calcitization bears no relationship to the presence and timing of unconformities. Porosity creation and modification occurs deep in the subsurface.

Petrographic, fluid inclusion and isotopic data for elemental sulphur are compatible with sulphur generation by the reaction of sulphate and sulphide (Orr, AAPG Bull., 50, 2295-2318, 1974) as opposed to simple oxidation of H_2S. The data also indicate that sulphur was present in the reservoir as an immiscible liquid. (Authors' abstract)

VIBETTI, N.J., KERRICH, R. and **FYFE, W.S.**, 1989, Hypersaline fluids discovered in the Troodos ophiolite, *in* I.L. Gibson, J. Malpas, P.T. Robinson and C. Xenophontos (eds.), Cyprus Crustal Study Project: Initial Report, Hole CY-4: Geol. Surv. Canada, Paper 88-9, p. 229-234.

Two distinct hydrothermal fluids have been identified in the Troodos ophiolite from fluid inclusion studies of alteration minerals encountered in drillhole CY-4. Alteration mineral assemblages signify zeolite (laumontite-stilbite-analcite-calcite±gypsum) to greenschist (albite-actinolite-epidote-anorthite-quartz-diopside) facies conditions of hydrothermal alteration. The first population of P fluid inclusions are two-phase liquid + vapour, with Te = -31 to -19°C, Tm = -5 to -0.1°C, and Th = 140 to 354°C, corresponding to NaCl thermal waters of 8 to 0.7 wt % NaCl eq. salinity, plausibly evolved seawater. A second population of P fluid inclusions contain liquid, vapour ± NaCl dxls, where Te = -55 to -43 °C, Tm = -34 to -0.3°C, and Th = 130 to 300°C. Such fluids are dominantly hypersaline $CaCl_2$-NaCl brines, involved in local Ca-metasomatism of the ophiolite. Enhanced salinities may have resulted from the reaction of seawater with peridotite to produce serpentine + brine. Sporadic low salinity fluids may represent either condensate from a boiling hydrothermal fluid, or a third, late-stage aqueous reservoir. (Authors' abstract)

VICENZI, E.P., McBIRNEY, A.R. and **WATSON, E.B.**, 1989, Melt inclusions in plagioclase megacryst-rich basalt (abst.): Eos, v. 70, p. 498. First author at Dept. Geol, Rensselaer Polytech. Inst., Troy, NY 12181-3590.

Silicate melts trapped by crystals during solidification can yield important clues to early magmatic liquids. However, reconstructing the original liquid composition from melt inclusions poses several problems: (1) growth of a rind of the host phase along the walls of the inclusion will produce an evolved liquid in the interior, (2) determination of the volumetric relationship between the rind and the interior portions on the basis of a 2 dimensional section through the inclusions, and (3) the possibility of chemical interaction between the host crystal and melt following entrapment. Moreover, if the cooling rate (and/or P drop) is insufficient for the trapped melt to pass through the glass transition, growth of solid phases will replace the remaining volume of melt, and information concerning the composition of each d phase (including intracrystalline zonation) must be obtained in order to compute the melt inclusion composition.

Holocrystalline melt inclusions in plagioclase megacrysts are common in plagioclase-rich (up to 40 vol %) basalts erupted on the island of Marchena, Galapagos Archipelago. Surrounding each inclusion is a plagioclase aureole that is progressively zoned in composition from that of the host crystal (An_{84}) to An_{30} at the interface with the polycrystalline portion of the inclusion. The interior fraction contains an intergrown mass of evolved anhedral dxls of plag (An_{30}), olivine (Fo_{55}), zoned augite (Mg# = 67/60), and FeTi oxide. Backscattered electron images were digitized to estimate modal abundances of all phases, including the zoned portions of plagioclase and clinopyroxene. Regardless of the assumptions concerning the 3D geometry of the inclusions, plagioclase dominants the phase volume (62-71%). The large proportion of plagioclase suggests that the trapped melt resorbed some portion of its host. However, the calculated melt composition would be in equilibrium with a plagioclase less calcic than the host, i.e., An_{60}. In addition, the Mg# of the calculated liquid is small (53.0) relative to the bulk rock (60.3). Possibilities for such compositional discrepancies will be discussed. (Authors' abstract)

VICIL, M. and **SADIKLAR, M.B.**, 1989, New microscopic observations of a skarn ore mineralization from Kotana (Giresun, N. Turkey) (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 217 (in German) (supplementary issue to European J. Mineral., v. 1.).

The skarn ore occurrence ca. 28 km S of the harbor of Giresun (E shore of Black Sea) formed at the contact of granodiorite with Mesozoic carbonates. It bears magnetite, pyrrhotite, pyrite, chalcopyrite, sphalerite, martite, marcasite, goethite and lepidocrocite plus garnet, epidote, tremolite, actinolite, quartz, etc. Th of fluid inclusions in sphalerite and quartz ranged from 550 to 650°C. (From the authors' abstract translated by A.K.)

VIETS, J.G., LEACH, D.L. and **MOSIER, E.L.**, 1989, Two distinct ore fluids in the Viburnum Trend; genetic implications, *in* R.D. Hagni and R.M. Coveney, Jr., eds., Mississippi Valley-type Mineralization of the Viburnum Trend, Missouri: Univ. Missouri at Rolla, Dept. Geology and Geophysics, Rolla, MO, Guidebook Series, v. 5, p. 155-165.

Only literature data given. (H.E.B.)

VIKRE, P.G., 1989a, Fluid-mineral relations in the Comstock Lode: Econ. Geol., v. 84, p. 1574-1613. Author at ASARCO, Inc., 510 East Plumb Lane, Reno, NV 89502.

At least one Cretaceous and several Miocene hydrothermal events were imposed on Comstock district rocks. The Comstock lode vein assemblage, which resulted from the youngest and only economically important event, consists of quartz, electrum, silver minerals (mainly acanthite), pyrite, base metal sulfides, and minor amounts of calcite, sericite, chlorite, K feldspar, and albite. Andesite adjacent to veins is altered to quartz, sericite, and pyrite at vein contacts and quartz, sericite, montmorillonite, chlorite, and pyrite distally. Kaolinite is present in wall rocks adjacent to vein segments in which boiling occurred. Addition of the external components water, CO_2, and sulfur gases sufficed to produce all Comstock vein alteration assemblages.

Based on paragenetic and fluid inclusion studies, multiple generations of hydrothermal fluid formed Comstock district veins, but the earliest and highest T fluid deposited ore minerals. It ranged in T from >300°C at the north end of the lode (Cedar Hill) to <235°C at the south end of the lode (American Flat), contained <1 to >6 wt % NaCl, and was composed of both meteoric and magmatic water, according to fluid isotopic analyses. Younger cospatial fluid(s) contained up to 2.1 wt % CO_2. The thermal center of the Comstock lode hydrothermal system, Cedar Hill, is also the site of the highest measured ore fluid salinities.

Ore fluid isotherms, and to an extent, salinity isopleths, display reversals and convolutions that are spatially related to bonanzas. These sharp T gradients, coupled with mixing of ore fluid and at least one other high-T fluid, indicated by enthalpy-salinity relationships and deuterium enrichment, most likely caused precipitation of ore minerals. Sphalerite and electrum compositions indicate that bonanzas were deposited over a narrow range of fS_2 = -13.5 to -15.2, while sphalerites from low-grade and barren vein segments indicate more widely variable fS_2. Au-Ag ratios both in electrum and bulk ore appear to be T controlled as higher T generally correlate with Au/Ag ratios. Local boiling of

250° to 285°C fluid provides a paleosurface datum, but vein T >300°C require up to 3800 ft (1152 m) of cover over the tops of bonanzas during mineralization.

The distribution of both ore-stage and late vein calcite partially reflects hydrothermal fluid circulation patterns. In veins at district margins, the abundance of late calcite marks the demise of hot water circulation and the influx of large amounts of cold Miocene ground water into vein interstices. (From author's abstract by E.R.)

VIKRE, P.G., 1989b, Ledge formation at the Sandstorm and Kendall gold mines, Goldfield, Nevada: Econ. Geol., v. 84, p. 2115-2138. Authors at ASARCO Inc., 510 East Plumb Lane, Reno, NV 89502.

Au ore at the adjacent Sandstorm and Kendall mines occurs in silicified fissures or ledges that formed by both open-space deposition and replacement of Miocene rhyolites. En echelon Sandstorm-Kendall ledge segments consist of six assemblages which from oldest to youngest are: (1) ledge replacement quartz, (2) barite + sulfides, (3) quartz + pyrite + barite, (4) quartz + barite + kaolinite breccia, (5) vuggy quartz, and (6) lateral replacement quartz. A large range in Th (292°-100°C), salinities (0.2-7.9 wt % NaCl), isotopic compositions (δD, +3 to -137‰; δ^{18}O, +4.2 to -17.6‰) and gas concentrations (3.8-27.5 wt % $CO_2 + H_2S + SO_2 + N_2$) is observed in quartz and barite of the six assemblages. Isotopic T calculated for δ^{34}S(pyrite-alunite) and δ^{34}S(pyrite-gypsum) in wall-rock mineral assemblages range from 200° to 356°C.

Au occurs as inclusions in Cu sulfosalts (mainly luzonite and famatinite) and barite of assemblage (2), and in quartz and barite of assemblage (4). It is analytically detectable in assemblages (1) and (3). Rhyolites enclosing the six assemblages are altered to quartz + kaolinite or alunite adjacent to ledge segments, and to illite and montmorillonite-dominated zones with distance from the ledge. Quartz and kaolinite are the stable silicates in the ledge.

According to fluid isotope compositions and salinities, assemblages (1), (2), and (3) precipitated from heavy, pre-Miocene formation water, probably modified seawater, mixed with Miocene meteoric and magmatic water. Assemblage (4) was deposited by pre-Miocene formation water that either mixed with magmatic water or was enriched in δ^{18}O by exchange with Paleozoic metasedimentary rocks that underlie Goldfield. Assemblage (5) largely precipitated from Miocene meteoric water. Assemblage (6) fluid, which laterally replaced extensive volumes of andesite with quartz, is also Miocene meteoric water, but silicified andesite beneath laterally replaced andesite formed from δ^{18}O-enriched pre-Miocene formation water or increments of magmatic water. S isotope compositions permit derivation of barite from underlying Paleozoic metasedimentary rocks, which contain bedded barite deposits elsewhere in southwestern Nevada, and sulfide S from Tertiary intrusions. Small amounts of organic matter in barite may also have been derived from Paleozoic rocks.

Mineralization may have formed within hundreds of feet below the paleosurface. However, ledge fluid inclusions T exceeding several hundred °C at such shallow depths require a combination of thicker premineralization cover, fault displacements, lithostatic P, and more thorough evaluation of fluid inclusion phase ratios and gas compositions.

Distinguishing features of Sandstorm-Kendall ledge formation—near-surface fluid inclusion T exceeding 250°C, high-T gradients, disparate and distal water sources, internal ledge brecciation and sedimentation, and gas-rich fluids containing $H_2S + SO_2$—are consistent with rapid, very shallow emplacement of magma beneath Goldfield. Since ledges are essentially coeval with rhyodacite, latite, and andesite in the main district, subvolcanic intrusions or diapirs of these rocks probably supplied thermal energy for mineralization both there and at Sandstorm-Kendall. (From author's abstract by E.R.)

VOEVODIN, V.N. and **PROKOPOV, N.S.**, 1988, Subsurface tungsten ore mineralization of the open hydrothermal systems in Chukotka: Abstracts of the 4th Session of the N. Caucasian Division of the All-Union Mineralogical Society, Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 44-45 (in Russian). First author at Far-East Sci.-Research Inst. of Min. Raw Materials, Khabarovsk, U.S.S.R.

Ore bodies of the Skalistoe deposit in sulfidized Permian-Triassic terrigenic rocks consist of three types: (1) mylonitization zones mineralized with quartz and chalcedony, (2) quartz-chalcedony-argillite veins, (3) linear zones of travertine-like rocks. Radial aggregates and platy xls of hubnerite occur in the rocks. By means of vacuum decrepitation, relatively high Td of 300-330°C was found for hubnerite, by gas chromatography $H_2O \gg CO_2$ (+ traces of reduced gases). (A.K.)

VOEVODINA, S.A., 1988, Salt composition of inclusions in mineral associations as an indicator of the erosion level of the tin-ore occurrences in Chukotka: Abstracts of the 4th Session of the N. Caucasian Div. of the All-Union Mineralogical Soc., Terskol, April 1988, printed at Perm Polytechnical Inst., Perm, U.S.S.R., p. 51-52 (in Russian). Author at Far-East Sci.-Research Inst. Mineral Raw materials, Khabarovsk, U.S.S.R.

Salt composition of G/L inclusions was determined by the water leachate method, described by A.A. Moskalyuk, from ore mineral associations and barren metasomatites. Cassiterite-silicate occurrences, associated with volcanic-plutonic complexes in the area of Zaliv Kresta (Cross Bay) along the margin of the Echkachek volcanic-tectonic depression [were studied] (the deposits: Erutta, Amgen', El'maun, Stoybishchnoe). In ore fields located in volcanic rocks, sheet metasomatic alterations are very common, being mostly propylitization. Numerous deposits bear disseminated boron mineralization (axinite and tourmaline) and barren quartz or poorly mineralized quartz-sericite, quartz-sulfide and quartz-chlorite metasomatites. Some of these metasomatites are associated with tin ore bodies. At Erutta deposit the ore bodies are quartz-tourmaline metasomatites and vein fillings; at El'maun—quartz-tourmaline-chlorite and quartz-chlorite metasomatites; at Amgen' and Stoybishchnoe—quartz-chlorite metasomatites. In fine-grained cassiterite ores there occur also sulfide minerals in variable amounts.

Analyses of water leachates show very wide variations of essential cations Na, K, and Mg, but these variations are fully regular. Every ore mineralized body has typical cation ratios with a leading role of one of the cations. Bicarbonate and chloride ions are the main anions, occurring in variable amounts. Sulfate occurs usually in low contents, fluoride ion is present in all samples, but its concentration is low. At all the deposits, the barren and tin-poor metasomatites yielded the same Cl-HCO_3-Na or HCO_3-Na types of the parent fluids. Commercial ores formed from Cl-K (Erutta and Amgen'), HCO_3-Mg and HCO_3-K (El'maun) and HCO_3-Mg (Stoybishchnoe) solutions. Thus, the solution type does not determine whether solutions are barren or ore-forming. Ores may precipitate from various solutions. Evolution of the solutions goes from the Na-type to the K- or Mg-type, and the type of the hydrotherms is most probably a function of depth of ore formation. Na-type is typical of deep levels of mineralization; decreasing depth has increasing K role; and the subsurface levels are characterized by solutions rich in Mg and Ca. This sequence $Na \rightarrow K \rightarrow Mg$ is in agreement with their decreasing chemical activity. Thus, from the domination of one of these ions one may deduce the level of erosion, and the conclusions are in agreement with the reconstructions obtained from geological, mineralogical and geochemical observations. Erutta deposit is mostly deeply eroded, then in sequence—Amgen', El'maun, and Stoybishchnoe, each less eroded. This method the authors recommend also for deposits of other metals. (Author's abstract translated by A.K.)

VOGEL, T.A., MILLS, J.G, Jr., AINES, R.D. and MERZBACHER, C.I., 1989, Pre-eruptive volatiles in a chemically zoned magma body based on melt inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A271. First author at Dept. Geological Sciences, Michigan State Univ., East Lansing, MI 48824.

Pre-eruptive water contents of magma bodies have been inferred from an infrared spectrographic study of over 250 melt inclusions from chemically zoned ash-flow sheets from the Southwest Nevada Volcanic Field. We report here on the Ammonia Tanks Member of the Timber Mountain Tuff that contains large chemical variations. Inferred pre-eruptive water contents are 2.8 to 3.1 wt % water in the lower silica portion to 4.0 to 4.5 wt % in the high-silica portion. Glass inclusion were measured in abundant feldspar and rare quartz phenocrysts separated from glassy pumice fragments. The chemical variation of these pumice fragments from the ash-flow sheet is from 57 to 76 wt % silica. The chemical compositions of the inclusions are similar to those of the glass groundmass (anhydrous). T variation of these pumice fragments is from 910 to 780°C (based on ilmenite-magnetite compositions). Glass inclusions are abundant in phenocrysts in the lower silica pumice samples, but rare in the high-silica ones. In contrast to the Bishop Tuff (Anderson et al., 1989), no CO_2 was detected in any of the glass inclusions (detectability limit of about 50 ppm) [Correction: some CO_2 was found]. Glass inclusions can be measured as small as 25 microns in diameter. There is no variation in water content within an inclusion. However, large variations occur among inclusions within single phenocrysts, especially the feldspars—the lower water values are attributed to degassing during decompression. The higher values we consider to represent near pre-eruptive water contents, but these measurements are low estimates because all inclusions contain gas bubbles. (Authors' abstract)

VOGTMANN, J. and **FRIEDRICH, G.,** 1988, Physico-chemical processes in sedimentary rocks of the Venn massif (abst.): Fortsch. Mineral., v. 66, part 1, p. 161 (in German).

In the black and banded schists of Revin and Salm at the SE margin of the Venn massif, in the area subjected to "very low-grade metamorphism" in the north, there occurs a paragenesis of pyrite, Fe-poor sphalerite and chalcopyrite plus the main rock-forming mineral, Fe-rich chlorite. In the south, where "low-grade metamorphism" was recognized, pyrrhotite is the main ore mineral, accompanied by Fe-rich sphalerite, Fe-rich chalcopyrite, pyrite and Fe-poor chlorite. This systematic variation between the Fe-bearing sulfide and Fe-Mg silicate indicates a cation-exchange during metamorphism without changes of the bulk Fe and Mg contents. Chemical composition of chlorite depends not only on T. Chlorites from hemipelagic sediments of Revin were poor in manganese, but chlorites from the near-shore, deltaic sediments of Salm were richer in Mn [and the precipitation environment was more oxidizing]. Walshe's (1986) model of chlorite formation suggests that the expression 100 $Mg/(Mg + Fe^{2+} + Fe^{3+})$ is generally a function of T and redox potential of a thermal system where chlorite crystallizes. The T data obtained by this mode for the studied chlorites are consistent with the Th values. Fluid inclusion studies in vein quartz from the northern area yielded Th 150-300°C and in those from the southern area 200-400°C; salinity is low and ranges from 2 to 8 wt % NaCl eq.; noticeable contents of CO_2 and CH_4 are sporadically observable. Fe-poor sphalerite from a young extension fissure yielded Th 60-90°C of highly saline solution with a complex composition, Te -72 to -70°C, Tm -35 to -21°C. The associate ankerite bears inclusions with Th 80-100°C, Te -65°C, Tm -19 to -16°C. (Authors' abstract translated by A.K.)

VOLFINGER, Marcel and **PASCAL, Marie-Lola,** 1989, Partitioning of chlorine between muscovite and HCl-buffered solutions from 400 to 600°C at 2 kbar: Eur. J. Mineral., v. 1, p. 791-800.

VOLYNSKY, A.B., BARANOVA, N.N., BANNYKH, L.N. and **SEDYKH, E.M.,** 1989, Solvent extraction electrothermal atomic absorption determination of Te in fluid inclusions in quartz: Proc. 26th Colloquium Spectroscopium Int'l, Sofia, Bulgaria, Abstracts, v. 3, p. 44 (in English). Authors at Inst. Geochem. and Anal. Chem., Moscow, U.S.S.R.

An extraction-atomic-absorption method has been worked out for determination of Te in fluid inclusions in quartz. After leaching with hydrochloric acid, Te is extracted by 0.01 M Ni diethyldithiophosphate in CCl_4. Graphite tubes without pyrocoating are used for the analysis.

Te concentrations in fluid inclusions from a Au-sulfide-Te ore deposit are variable in the range from $2 \cdot 10^{-6}$ to $7 \cdot 10^{-3}$ M dependence from mineral stages. (Authors' abstract)

VON DAMM, K.L., BEYNON, B.E. and **BIDDLE, J.A.,** 1989, Quartz solubility in salt solutions: Applications to hydrothermal systems (abst.): Eos, v. 70, p. 1396.

VOROBYOV, Yu.K., 1989, The origin of syngenetic inclusions in minerals (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 69. Also in 28th Int'l Geol. Cong. Abstracts, p. 3-311. Author at Inst. for Geol. of Ore Deposits, Mineral., Petrogr. and Geochem. of Acad. Sci., USSR (IGEM), Moscow, USSR.

An experimental study of the crystallization process in multicomponent media (solutions, melts and crystalline matrices) has shown that the growth of crystals is always accompanied with the separation of media components. Besides a local heterogenization of the medium almost always takes place at the growth front due to a higher concentration of impurities near the crystal and the appearance of impurity phases. It has been discovered that the trapping of inclusions is an indispensable stage in the growth of crystals in impure natural media.

Syngenetic inclusions along the growth zones are formed from the most impure part of the crystallization halo and are always either impurity phases (solid, liquid or gaseous) or an exhausted and impure medium. Mineralothermometry is particularly interested in the frequent phenomenon of local heterogenization and the accompanying exsolution of a gas, as the released bubbles are trapped in the crystal at a random ratio with the liquid. This is the reason why P syngenetic inclusions cannot serve as a basis for geothermometric measurements[sic]. As different crystals (and even different faces of a crystal) have differing distribution coefficients, the composition of syngenetic inclusions in paragenetic crystals of different minerals will also be different.

Syngenetic inclusions may be close in composition to the average composition of the crystal-forming medium, whereas their homogenization points may coincide with the real crystallization T only when the process of inclusion filling is separated from the growth process. This separation may occur during the filling of growth cracks or the intumescence of crystalline material on the etched surface of the seed. (Author's abstract)

VOYTOV, G.I., SHEBERDYEV, S.Sh., BERDYEV, K.B. and **KARPOV, V.P.**, 1989, Peculiarities of temporal changes of chemical and isotope composition of natural gases at local structures of the Sultansandzhar swell: Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 202-206 (in Russian). Authors at Inst. Phys. of the Earth, Moscow, USSR.

The paper presents data on the He, H_2, N_2, CO_2 and C to C_3 hydrocarbons. (A.K.)

VOZNYAK, D.K. and **KVASNITSA, V.N.**, 1988, Crystallized salt-melt inclusions: Geokhimiya 1988, no. 11, p. 1661-1664 (in Russian, translated in Geochem. Int'l, v. 26, no. 6, p. 115-118, 1989).

Inclusions of gas and of crystallized anhydrous salt melts are found in crystals of anorthoclase from linings of miarolitic cavities in olivine dacites from the Black Mtns., Transcarpathia, U.S.S.R. The gas inclusions show no change to -196°C and have 0.4 to 0.5 atm pressure at room T. The salt-melt inclusions consist of ~70% xls of six phases at room T, both isotropic and anisotropic; there is no visible liquid phase. Tt is 975-1000°C. On opening, the contents are hygroscopic ($CaCl_2$?). Te < 325°C. (E.R.)

VOZNYAK, D.K. and **VASILENKO, A.P.**, 1989, Physicochemical conditions of the localization of gold mineralization in highly metamorphosed mafic-ultramafic complexes in the Ukrainian Shield; according to data from studies of fluid inclusions: Dopovidi Akad. Nauk, Ukrains'koyi RSR, Seriya B, Geologichni Khimichni Biologichni Nauki, 1989, (12), p. 3-5 (in Ukrainian).

WALKER, J.C.G. and **LOHMANN, K.C.**, 1989, Why the oxygen isotopic composition of sea water changes with time: Geophys. Res. Letters, v. 16, no. 4, p. 323-326. Authors at Dept. Geol. Sci., The Univ. Michigan.

The O isotopic composition of sea water is determined by interactions with fresh, silicate rocks. Interactions at high T, principally hydrothermal interactions on the sea floor, make sea water isotopically heavier. Interactions of low T, including sea floor weathering but principally weathering of fresh, crystalline rocks on the continents, make sea water isotopically lighter. Any change in the relative rates of these high and low T interactions will cause a change in the composition of sea water. Extreme limits might be -15‰ relative to SMOW to +4‰. Possible rates of change appear to be quite slow, perhaps 1‰ in 10^8 years, because of the large size of the oceanic reservoir. Evolution in tectonic style over the course of earth history may have caused a change in the O isotopic composition of sea water as fresh crystalline rocks have been increasingly blanketed by weathered sediments and as deepening oceans have increasingly flooded the places where earth's internal heat is released at the surface. (Authors' abstract)

WALLACE, A.R., 1989a, The Relief Canyon gold deposit, Nevada: A mineralized solution breccia: Econ. Geol., v. 84, p. 279-290. Author at U.S. Geol. Survey, MS 905, Box 25046, Denver Federal Center, Denver, CO 80225.

The Relief Canyon Au deposit in the Humboldt Range of western Nevada is a low-grade, high-tonnage ore body of Tertiary or younger age. The host rocks include limestones of the Triassic Cane Spring Formation, which are overlain by shales of the Triassic Grass Valley Formation.

Episodic pulses of hydrothermal fluids were introduced along faults and possibly mixed with the ground water in the breccia zone. Initially, jasperoids formed along the faults, but later hydrothermal pulses introduced Au, silica, and F into both the early jasperoids and the unconsolidated cave-fill sediments to form the ore body. Continued solution-related brecciation chaotically disrupted the Au deposit.

Au, fluorite, pyrite, Ag, calcite, and fine-grained silica are the principal hydrothermal minerals in the deposit. Au was deposited as micron-sized flakes of native Au and rarely as electrum during a relatively late stage of silicification of the jasperoids, the carbon-rich zones, and the clay-rich matrix of the breccia. Fluorite was deposited with and later than the Au in the jasperoids, and it in part replaced the clay-rich breccia matrix. Sb, As, Hg, and Th are directly associated with Au in the ore body.

The deposit formed at a relatively shallow depth. On the basis of FI data, late-stage hydrothermal fluids related to Au and fluorite deposition were extremely dilute and near 200°C. The FI in fluorite show no evidence for boiling, but porous crackle breccias in the jasperoids suggest that hydrobrecciation took place. (From author's abstract by E.R.)

WALLACE, A.R., 1989b, Gold in the Central City mining district, Colorado: U.S. Geological Survey Bull. 1857-C, p. C38-C47.

Only literature data given. (H.E.B.)

WALTHER, J. and **ALTHAUS, E.,** 1989, Fluid systems and graphite formation in inclusions in drilling core samples of the KTB pilot borehole (abst.): Berichte der Deutschen Mineralog. Gesselschaft, no. 1, p. 195 (in German) (supplementary issue to European J. Mineral., v. 1.).

Paleofluids in drilling core samples of the KTB pilot borehole were studied by the methods of microthermometry, Raman probe and infrared microscopy. Several fluid systems were found:

- aqueous solutions of variable salinity and density. This concerns mostly "alteration fluids" from S inclusions ($NaCl-CaCl_2-H_2O$, density 0.80-1.30 g/cm^3).
- gaseous systems, mostly older than the previous ones: $N_2 \pm CO_2$ (density 0.3-0.6 g/cm^3) and $CO_2 \pm N_2$ (density 0.8-1.1 g/cm3).
- carbon/graphite covered cavities (identification by Raman spectra) with CO_2 ($\pm N_2$) and H_2O (IR spectroscopy).

The latter are most probably relics of the graphite-forming reaction $CO_2 + CH_4 \rightarrow 2C + 2H_2O$. From the inclusions density, the PT values of graphitization can be estimated (to be 2.5-3 kbar at 300-400°C. (Authors' abstract translated by A.K.)

WALTHER, J.V. and **BRADY, P.V.,** 1989, Prediction of ion association in supercritical H_2O fluid mixtures (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A102.

WAN, J., NORMAN, D., KYLE, P. and **ZHANG, Z.,** 1989, Analysis of gold and other elements in fluid inclusions from the No. Creede vein system, Colorado and Xinjian Province, NW China (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 70. First author at Dept. Geosci., New Mexico Tech., Socorro, NM 87801.

Au, Ag and about 25 other elements were quantitatively measured in FI by means of INAA and AA analysis. Inclusions were opened in vacuum, the volatiles measured, and the salts removed by leaching. Splits of quartz removed prior to, and after decrepitation and leaching, were also analyzed by INAA. Both Creede and Xinjian quartz have elevated levels of K, Rb, Ba, and W that make analyses of these elements suspect. Mass balance of elements removed from the quartz when inclusions are opened indicates that Au is leached from opened inclusions almost as well as Na. The amount of salts in leachates correlates well with salinity determined by Tm ice.

Au in Creede inclusions range from 0.5 ppb to 34 ppb, and Ag from less than 70 ppb to 300 ppb. The Au, CO_2, and H_2S analyses from inclusions that exhibit signs of fluid boiling, correlate negatively with T. We interpret this data to reflect loss of gaseous constituents from ore solutions as a result of boiling, and deposition of Au resulting from decomplexation with bisulfide ions. Analyses of Xinjian inclusions yielded Au concentrations of up to 18 ppb; Ag values ranged up to 170 ppb.

Calculated solubilities of ore metals for Creede and Xinjian ore solutions indicate that Zn and Ag levels were near to saturation, whereas Au appears to have been under saturated. The levels of Au in inclusions from Creede, Xinjian and one other deposit that has been studied indicates maximum values of 10 to 30 ppb. These levels of Au in ore solutions are certainly sufficient to form Au ores, and are more than an order of magnitude higher than reported from active geothermal systems. The limiting factor on the levels of Au in ore solutions may be the amount available in country rocks. (Authors' abstract)

WAN, Yong-wen and **ZHU, Zi-zun,** 1989, Study on the inclusions in the fluorites from Suichang and Lishui: Chinese Sci. Bull. (Kexue Tonghau), v. 34, no. 13, p. 1125-1129 (in English). First author at Chengdu College of Geology.

The fluorites from Suichang and Lishui counties in Zhejiang Province occur in middle-low-T hydrothermal fluorite deposits with two stages of mineralization. The well-developed gas-liquid inclusions, irregular, water-drop, ellipsoidal or spherical in shape, are distributed as chains, bands or sporadic dots in the fluorites. The size of the inclusions varies from 5 to 107 μ. The ratio of gas/liquid in the inclusions ranges from 5 to 15%. (Authors' abstract)

Th ranged from 83-190°C (using sodium tungstate, sulfur, naphthalene, and sugar as standards); IR measurements were made of fluorite plates and of powdered fluorite in pressed KBr plates. (E.R.)

WANAMAKER, B.J. and **EVANS, Brian,** 1989, Mechanical re-equilibration of fluid inclusions in San Carlos olivine by power-law creep: Contrib. Mineral. Petrol., v. 102, p. 102-111. First author at Dept. Materials Science and Engineering, Cornell Univ., Ithaca, NY 14853.

FI in San Carlos olivine stretch via plastic mechanisms when heat-treated at 1400°C and 0.1 MPa in controlled fO_2 atmospheres for several days. Measurable changes in both inclusion dimensions and fluid densities occur; densities decrease from ≈1.0 to ≈0.7 g/cc. Stretching is fastest along <100>, and slower along <001> and <010>. The dislocation microstructure around the inclusions suggests that creep mechanisms operate. Uncertainties in the experimental determinations of stretching rates result from optical resolution limits, errors inherent in measuring Th, uncertainties in the fluid equation of state, and changes in fluid chemistry during the heat-treatment. Inclusion stretching by dislocation creep can be treated using a model developed for hot isostatic pressing. In this model, we assume spherical symmetry of plastic flow, that the material yields by steady-state power-law creep, and that the parameters for the constitutive law and fluid equation of state are known. Stretching rates are predicted to depend on the difference between the fluid P and the external P, the T, the constitutive law governing power-law creep, and geometry. Predicted stretching rates show fair, but not exact, agreement with experimentally measured rates. The amount of stretching predicted by the model is in rough agreement with estimates based on dislocation microstructures around natural inclusions, if xenolith ascent rates are of the order of 1 cm/s or faster. (Authors' abstract)

WANG, Henian, ZHANG, Jingrong and **DAI, Aihua,** 1989, Geochemistry of the Hetai gold deposits in the altered zone: Mineral Deposits, K'uang Ch'uang Ti Chih, v. 8, (2), p. 61-71 (in Chinese).

Indexed under FI. (E.R.)

WANG, Huayun, HU, Kechang, WU, Gangpei, CHEN, Hongqi and **LIU, Congben,** 1989, Genesis of stratabound mercury deposits in the border area between Hunan and Guizhou, *in* Yan Junping, ed., Geology of mercury deposits in Guizhou, China, p. 99-182.

Indexed under FI. (E.R.)

WANG, Kuiren and **ZHOU, Youqin,** 1989, Geochemistry study on a W-ore deposit in Xinjian, China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-324. Authors at Univ. Science and Technology, Hefei, Anhui, P.R.C.

The W-ore deposit is situated in Bole state of Xinjian province, China. There is a Hercynian biotite-monzonitic granite nearby. The petrochemical characteristics are high-silica, rich-alkali, poor-Fe, Mg, Ca, Ti, P, etc. The deposit belongs to quartz vein type in external zone. The type of mineralization is W-Cu mineralized. Mineral associations are (1) tourmaline-muscovite-wolframite, (2) arsenopyrite-wolframite-cassiterite, (3) chalcopyrite-chalcocite-wolframite.

H, O isotope composition: $\delta^{18}O$ value (+12.89% [sic]) shows that the granites were formed by deep-melting from crustal sediment. δD value is -72% for quartz in granite, -85% for quartz in ore veins. S isotope composition: $\delta^{34}S$ values are +0.59 - +0.84% and +1.24 - +3.24%, which have the property of sulfur from magma. Mineralizing fluid: the main component of gas-phase is CO [sic], H_2, CH_4. The components from liquid-phase are K^+, Na^+, Ca, SO_4^{2-}, F^-, Cl^-, etc.

Physical-chemistry conditions of deposit formation: the inclusion Th (326-346°C) for quartz and O-isotope T (390-380°C) for quartz-wolframite show that this deposit is high-T hydrothermal deposit. (From authors' abstract by E.R.)

WANG, Zhitian and **QIN, Kezhang,** 1989, Rare earth element geochemistry of porphyry copper multi-metal metallogenic series and its application in ore exploration in the Manzhouli-Xinbaerhuyouqi area (China): Diqiu Huaxue 1989, (4), p. 304-314 (in Chinese). Authors at Beijing Inst. Miner. Resour. Geol., CNNC, Beijing, P.R.C.

Rare-earth elements (REE) geochem., petrochem., FI, trace element, and stable-isotope data were obtained of the porphyry Cu ore deposits in the Manzhouli-Xinbaerhuyougi area of China. The REE patterns in various rocks can be divided into three types. REE were introduced as chlorides, the F^- complex, and F^- and $CO_3{}^{2-}$ complexes in the Q (quartz)-Kf K feldspar, Q-Ser (sericite) and I (illite)-H (hydromica) alteration zones of the Wushan deposit. Two phases of alteration are recognized, overlapping each other. Following the development of Q-Kf, REE in the porphyry increases (heavy REE increases more rapidly). ΣCe/ΣY decreased, and Eu became depleted. Formation of the I-H zone in the wall rock led to strong REE leaching, accompanied by activation and transport of Mo. The inner I-H zone was superimposed by Q-Ser alteration, leading to redeposition of the previously leached REE and reactivation and re-enrichment in Cu, Mo, Ag, Pb, and Zn. This process has a great bearing on the ore mineralization. Eu-depletion is of significance for indicating mineralization. (CA 112:202234w)

WATSON, E. and **BRENAN, J.M.,** 1989, Small-scale distribution of C-O-H fluids in deep-seated rocks and its implications for diffusional mass transport (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-338-339. Authors at Rensselaer Polytech. Inst., Troy, NY.

Recent experimental studies in our lab have provided fundamental information concerning the geometry of C-O-H fluid distribution on the scale of individual grains in high-grade rocks (900-1200°C, 5-20 kbars; see Watson and Brenan, 1987). Two types of distribution are well documented: (1) the fluid may exist as isolated pores at grain corners, (2) it may form an interconnected network of trigonal prism-like tubules along grain edges. No case has yet been observed in which C-O-H fluid wets all grain boundaries. For fluid volume fractions less than 1-2%, the crossover in behavior from type 1 to type 2 occurs when the dihedral angle (Θ, formed between surfaces of two contacting crystals bounding a fluid-filled cavity) assumes a value of 60° or lower. The value of Θ for any given mineral/fluid assemblage is determined by the relative magnitudes of the interfacial energies involved, according to the well-known "wetting" relation

$$\gamma_s s/2\gamma_s f = \cos(\Theta/2)$$

where γ refers to the energy per unit area of the subscripted interface, either solid-solid (ss) or solid-fluid (sf). For the variety of silicates and fluid compositions investigated thus far, Θ ranges between ~40 and ~90°, the lowest values pertaining to aqueous saline fluids in quartzite and the highest values to CO_2 in quartzite, dunite, and "feldsparite." Qualitative values for CO and CH_4 in dunite are also high ($\geq 90°$). Accordingly, on the basis of data available at the time of this writing, it can be concluded that the rocks most likely to have an interconnected fluid phase are quartz-rich, mid- to lower-crustal rocks containing saline H_2O.

The effects of changes in P and T upon Θ have been investigated in detail only for San Carlos olivine (~Fo_{90}; see Brenan and Watson, 1988).

For all types of rocks, the distinction between interconnected ($\Theta \leq 60°$) and noninterconnected ($\Theta > 60°$) fluid is of paramount importance when considering chemical transport: Isolated, grain-corner pores ($\Theta > 60°$) provide no path for fluid flow, nor do they contribute to diffusional transport on a scale greater than their own dimensions. Three-dimensionally interconnected grain edge channels ($\Theta \leq 60°$), on the other hand, may constitute avenues not only for Darcy flow but also for diffusion of ions dissolved in a static fluid. We have investigated the latter possibility specifically for diffusion of Fe in synthetic dunites containing CO_2-H_2O fluids.

[The study suggests] that neither the CO_2 fluid nor the olivine grain boundaries contribute significantly to diffusive transport of Fe at these conditions. This conclusion is not unreasonable in view of the isolated nature of CO_2-filled pores. The much higher bulk diffusivity characteristic of H_2O-bearing dunite is readily attributed to the complete interconnectivity of a fluid of this particular composition. Considering the small volume fraction of fluid and its probably modest capacity to dissolve the Fe component at the experimental conditions, the measured bulk-rock diffusion coefficient implies that diffusion in supercritical H_2O is extremely fast. (From authors' abstract by E.R.)

WATTENBARGER, A.C., 1989, Base and precious metal mineralization in the Blackhawk Mining District, San Bernardino County, California: MS thesis, Univ. California, Riverside, CA.

Mineralization in the Blackhawk Mining District was confined to Paleozoic marble of the upper plate of the Santa Fe thrust fault. This structure is part of an E-striking thrust system, which extends along the northern slope of the San Bernardino Mountains. Information gained during this study has important implications regarding the role this fault system played in the formation of base and precious metal mineralization along the range front. This study includes detailed mapping, petrography, geochemistry and fluid inclusion analysis in order to elucidate the nature of the deposit, and to understand its origins in a regional context.

A spatial relationship exists between historically productive workings and porphyritic dikes which intrude the marble. The marble was widely bleached in response to low grade contact metamorphism. In the vicinity of the Santa Fe thrust, the marble was bleached and intensely stained with iron oxide. Mineralized rock occurs not only within bleached and oxide stained marble, often adjacent to a carbonaceous/graphitic marble bed, but also occurs in unaltered gray marble.

Mineralized rock occurs as small, metasomatically emplaced, sulfide-rich, siliceous mantos that are cut by the subsidiary faults of the younger Santa Fe thrust system. Lack of mineralization in the lower plate supports the conclusion that the mantos were tectonically dislocated during post-mineralization orogenesis. Based on petrographic investigations, two stages of primary precious and base metal deposition are recognized. The first stage involved metasomatic replacement of marble by hydrothermal quartz, Au, auriferous pyrite, chalcopyrite and galena. The second stage included brecciation of the hydrothermal quartz, deposition of quartz in open spaces, and precipitation of Au, pyrite, chalcopyrite, galena and sphalerite. After mineralization, the marble and mineralized rock were fractured and barren calcite veins were formed. This event was associated with a phyllic/argillic hydrothermal event developed along the Santa Fe thrust system. Phyllic/argillic alteration was overprinted on primary mineralized rock. The mineralized rock has been pervasively oxidized. During oxidation base and precious metals underwent limited remobilization.

A geochemical survey was conducted in order to recognize elemental anomalies and correlations within the district. Results of this survey include a high correlation of base and precious metals, reflecting primary mineral associations. Trace element concentrations are similar to those in a skarn hosted base and precious metal occurrence located south of the thesis area adjacent to Mesozoic intrusives. The similarities imply a common metasomatic parentage. The Santa Fe thrust zone lacks geochemical anomalies, as do later normal faults, indicating these structures did not play a role in the primary development of mineralized rock.

Fluid inclusions in quartz crystals from the mantos were studied. The fluids involved in the second stage of primary mineralization were CO_2-rich, had salinities between 0 and 9 wt % NaCl eq., and were trapped near 300°C. These characteristics are suggestive of a hydrothermal origin. S fluid inclusions from a quartz monzonite hosted pegmatitic dike possess similar characteristics, indicating the hydrothermal episode was associated with a late-stage magmatic event. Fluid inclusions in quartz adjacent to phyllic altered rock, and in calcite veins in argillized gneiss, lack CO_2, have salinities between 0 and 7 wt % NaCl eq., and were trapped between 100° and 210°C. These inclusions were likely formed during a late-stage, post-mineralization hydrothermal event, centered along the Santa Fe thrust. This event may be responsible for the development of intense oxide stained rocks located immediately above the Santa Fe thrust fault. After hydrothermal alteration, the mineralized rock was deformed and brecciated during extensive Quaternary slide events. (Author's abstract)

WEBSTER, J.D. and **DUFFIELD, W.A.,** 1989, Pre-eruptive abundances of H_2O, Cl, F, B, Sn, Mo, W and other lithophile trace elements in Taylor Creek Rhyolite, New Mexico, U.S.A. (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A57. First author at Grant Inst. Geology, King's Buildings, West Mains Rd., Univ. Edinburgh, Edinburgh EH93JW, Scotland.

Glass inclusions in quartz phenocrysts from four high-silica rhyolite flows of the Sn-mineralized, Oligocene, Taylor Creek Rhyolite, New Mexico, have been analyzed for major and minor elements by electron microprobe and for H, Li, Be, B, Rb, Sr, Y, Nb, Mo, Sn, Cs, Ce, W, Th, and U by ion microprobe. Glass inclusion compositions may be representative of melt compositions.

Glass inclusions from two lava flows contain crystals. These inclusions have been rehomogenized at 900°C and 4 kbar; compositions of crystals and rehomogenized glass indicate that crystals formed in inclusions after trapping. Inclusions from one flow contain glass, F-rich biotite, and fluorite; the rehomogenized glass from these inclusions contain up to 4.4 wt % F and 0.49 wt % Cl. Inclusions from the second flow contain glass and F-rich muscovite; the rehomogenized glass contains >2 wt % F and >0.4 wt % Cl.

The other two flows contain crystal-free glass inclusions, and preeruptive water contents range from 0.4 to 1.9 wt %. SiO_2 is low and Al_2O_3, Na_2O, and K_2O are high in these inclusions relative to associated whole rocks, suggesting inclusion compositions have been influenced by post-trapping quartz crystallization and/or disequilibrium growth processes. Major element data, however, constrain enrichments of all elements (except SiO_2) due to such processes to less than or equal to 14% relative.

Preliminary study of crystal-free inclusion compositions by factor analysis shows no regular relationships between volatiles (H_2O, B, F, Cl) and other elements analyzed. Positive correlations are observed between elements within the group: Th, U, Rb, Y, Cs, and Nb. (Authors' abstract)

WEBSTER, J.D., HOLLOWAY, J.R. and **HERVIG, R.L.**, 1989, Partitioning of lithophile trace elements between H_2O and $H_2O + CO_2$ fluids and topaz rhyolite melt: Econ. Geol., v. 84, p. 116-134. First author at Dept. Geol., Arizona State Univ., Tempe, AZ 85287-1404.

Experiments have been conducted with H_2O and $H_2O + CO_2$-bearing fluids and melts of a Cl-, F-, and lithophile trace element-enriched vitrophyre associated with topaz rhyolite from Spor Mountain, Utah. The starting material is mildly peraluminous and contains 1.25 wt % F and 1500 ppm Cl. The experiments were conducted with fO_2 controlled near Ni-NiO, at P of 0.5 to 4 kbars, and at 770° to 950°C. Fluid/melt trace element distribution coefficients (D_i) were calculated for Li, Be, B, Rb, Sr, Y, Zr, Nb, Cs, Ba, Ce, Th, and U after ion microprobe analysis of starting material and run product glasses. The concentration of element i in the fluid was calculated by mass balance and the fluid/melt distribution coefficient, D_i, was calculated as (ppm by weight of i in fluid/ppm by weight of i in melt).

The partitioning of Li, R, Sr, Y, Nb, Cs, and Ce between aqueous fluids and melts of topaz rhyolite composition depends strongly on T and P. At 0.5 kbars Li, Rb, Sr, Y, Nb, Cs, and Ce concentrate in the fluid at ≥900°C; at 2 kbars this same group of lithophile elements, except for Sr, concentrate in the fluid at $T \geq 900$°C. Be, B, and Ba partition in favor of the melt at 0.5 and 2 kbars and at all T of this study.

In the presence of CO_2-free aqueous fluids at 4 kbars and at 770° to 950°C, all lithophile elements partition in favor of the melt. This behavior for lithophile elements mimics that of published data on the partitioning of Pb and Zn between rhyolitic melts and Cl-bearing fluids. Previous studies have demonstrated an equivalent effect of P on the distribution of chalcophile trace elements between granitic melts and Cl-bearing aqueous fluids.

Fluid/melt distribution coefficients for the lithophile trace elements are significantly smaller for topaz rhyolite melts in equilibrium with mixed $CO_2 + H_2O$ fluids than for topaz rhyolite melts plus CO_2-free aqueous fluids. There is no evidence for CO_2 complexing with the lithophile trace elements at $P \leq 4$ kbars.

For equilibrium between topaz rhyolite melt and aqueous fluids at 2 kbars and 800°C, the distribution coefficients of Li, Rb, Sr, Y, Nb, Cs, Ba, and Ce increase as the Cl concentration of the fluid increases from ≈0.2 m to >6 m. The data imply that the alkali elements (M) dissolve into the fluid as MCl° complexes and that Ce dissolves into the fluid as a $CeCl_3^{\circ}$ complex.

Water-saturated magmas of topaz rhyolite composition may become differentiated with respect to Li, Cs, and Rb (±Ce, Y, and Nb) if an aqueous fluid phase is evolved and moves through the magma under the influence of a T gradient that has a maximum T of at least 850° to 900°C. (Authors' abstract)

WEI, Jiaxiu, 1987, A study of fluid inclusions, thermal halos and genesis of the Baixiangshan iron deposit: Bull. of the Institute of Mineral Deposit, Chinese Academy of Geological Sciences, no. 20, p. 111-128. Author at Institute of Mineral Deposits, Chinese Academy of Geological Sciences.

The Baixiangshan Fe deposit is located in the southern part of the Ningwu (Nanjing-Wuhu) fault-depression basin with calcareous siltstone and fine-grained sandstone of Upper Triassic Huangmaqing Formation extensively distribution in that area.

Controlled by structures of this area, the ore body occurs at ortho-contact zone and endo-contact zone of the diorite-porphyrite body, with the metallogenic age being 105.2 Ma, slightly younger than the Baixiangshan intrusive body. The ore body is a concealed magnetite body, and the magnetite is associated with apatite, phlogopite, anhydrite, dolomite and calcite, all of these minerals containing plenty of fluid inclusions.

The inclusions can be grouped into fluid inclusions, gas inclusions, daughter-mineral-bearing triphase inclusions, liquid phase inclusions and melt inclusions. The homogenization and decrepitation techniques give ore-forming temperatures of 405-335°C, and the freezing method yields the salinity of ore-bearing thermal fluids of 20.50-14.60 wt %. The P at the ore-forming stage is 50 x 10^6 Pa, and the CO_2 partial P rises progressively with the gradual decrease in partial P of oxygen.

The trend surface analyses of thermal halos and evaporation halos indicate that the ore fluids come from northeast and southwest and migrate towards each other, with geothermal gradient being 142-100°C/km.

The researches on T-P geochemistry, thermal halos and evaporation halos demonstrate that the ore-bearing thermal fluids of the Baixiangshan type Fe deposit are mainly derived from the diorite porphyrite body in the crust. When the ore fluids ascend from the deep-seated magma source, with the gradual decrease in their T and concentration, they are likely to conduct metasomatic reaction with the wall rocks in the form of infiltration and diffusion, thus forming magnetite deposits. The Baixiangshan Fe deposit is a high-medium-T hydrothermal metasomatic deposit, with large quantities of magnetite precipitated in calcareous and magnesian strata. Ore prospecting, therefore, should be focused on the northeast and southwest of the ore district where diorite exists. A drill hole made at the Wanjiashan rock body northeast of the ore district has revealed a magnetite bed, which shows that the thermal halo and evaporation halo techniques are effective in prospecting for concealed ore bodies. (Author's abstract)

WEINER, Jonathan, 1989, Glacier bubbles are telling us what was in ice-age air: Smithsonian, v. 20, no. 2, p. 78-87.

A popular account of CO_2 in bubble sin ice and also amber. (E.R.)

WEISBROD, A., 1989, One and two phase equilibria in alkali chloride aqueous solutions, using synthetic inclusion data (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 91. Author at Ecole Nat. Sup. de G*ologie, B.P. 452 - 54001 Nancy, Cedex, France.

Usually, moderate to high T water-salt solutions are modelled by the well known H_2O-NaCl system. Indeed, Cl and Na are the major chemical species in most hydrothermal fluids. However, many fluids involve significant amounts of other components, such as Li and K chlorides. In order to model these more complex systems, experiments have been performed on the systems LiCl-H_2O, KCl-H_2O, RbCl-H_2O and CsCl-H_2O, using the synthetic FI technique.

One-phase systems. Lines of constant homogenization temperature (LC Th) (isochores with unknown density) have been determined at 400 to 600°C, 1 to 3 kbar, for 2 and 4.5 molal LiCl or KCl. The experimental results show that the slopes of the LC Th are similar to those obtained on the NaCl-H_2O system, for the same molalities. For a specified alkali chloride content and Th, the isochores in the systems LiCl-H_2O, NaCl-H_2O and KCl-H_2O are identical, although the corresponding densities are different. Preliminary results on RbCl-H_2O and CsCl-H_2O indicate similar behaviors.

Two-phase systems. The immiscibility domain (L + V) in the LiCl-H_2O and KCl-H_2O systems has been investigated at 500 and 600°C, and at P between 400 and 900 bars. At given T and P, the composition of liquid and/or the vapor has been determined by microthermometry, using the freezing point depression of ice or other convenient solids (sylvite, etc.). At given T and P, the larger the size of the cation, the wider the immiscibility gap between liquid and vapor. Preliminary data on the CsCl-H_2O system should confirm this relationship.

Using these results, the TPX evolution of complex hydrothermal systems, such as those related to the Li-rich Beauvoir granite, can be refined. (Author's abstract)

WEST, T.J., 1989, A petrographic study of the quartz and heavy minerals of the silica sand deposits of Black River, St. Elizabeth, Jamaica: J. Geol. Soc. Jamaica, v. 26, p. 22-27.

Indexed under FI. (E.R.)

WHITE, A.F. and PETERSON, M.L., 1989, Applications of D/H, and $^{18}O/^{16}O$ in assessing the fluid sources and chemical evolution of active hydrothermal systems (abst.): Eos, v. 70, p. 1378.

WHITE, B.S., BREARLEY, Mark and MONTANA, Art, 1989, Solubility of argon in silicate liquids at high pressures: Am. Mineral., v. 74, p. 513-529.

WHITE, B. and WYLLIE, P.J., 1989, Melting in the system $CaO-MgO-SiO_2-H_2O-CO_2$: A model for lherzolite in a mixed-volatile mantle (abst.): Eos, v. 70, p. 1394.

WHITNEY, D.L., 1989, A fluid inclusion investigation of the Skagit Gneiss migmatites, North Cascades, Washington (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A327. Author at Dept. Geological Sciences, AJ-20, Univ. Washington, Seattle, WA 98195.

The presence of a variety of migmatized and unmigmatized lithologies in the Skagit Gneiss, North Cascades, permits an analysis of the influence of rock type, metamorphic grade, and mechanism(s) of migmitization on the composition and distribution of fluids in a large-scale migmatite complex. Petrologic and fluid inclusion evidence indicates that the migmatitic core of the Skagit Gneiss was infiltrated by a water-rich H_2O-CO_2 fluid during upper amphibolite facies metamorphism. Abundant faceted, nearly pure CO_2 fluid inclusions, however, are present in intergranular microcracks and in isolated clusters in quartz in the leucosomes of migmatitic graywackes and pelites. No monophase CO_2 fluid inclusions have been observed in quartz in adjacent mesosomes or melanosomes nor in lower grade (unmigmatized) rocks of the Skagit Gneiss. Assuming that the fluid inclusions have remained closed chemical systems, these observations suggest that the presence of CO_2 in the leucosomes is related to the migmatization. The source of the CO_2 may be local—graphite or intercalated carbonates—since CO_2 inclusions are rare in migmatitic Skagit amphibolites and orthogneisses. Alternatively, the dominant mechanism(s) of migmatization may have differed in the metasedimentary rocks vs the meta-igneous rocks.

Anatexis probably commenced at or near peak metamorphic conditions (9 ± 1 kbars, 725 ± 50°C) and continued during nearly isothermal decompression. Isochores calculated for some texturally early aqueous fluid inclusions in quartz inclusions in garnets and plagioclase, and in some matrix quartz, intersect the estimated P-T path at ~7-9 kbars, 700°C. Most texturally early aqueous fluid inclusions in matrix quartz, however, contain low density fluid. These fluid inclusions have apparently stretched or leaked as a result of internal overpressures created during the steep decompression path and/or as a result of deformation of the rocks. All CO_2 fluid inclusions in leucosome quartz contain fluids with densities appropriate for trapping or reequilibration during decompression (Th = -26 to +29°C; peak at +17°C). (Author's abstract)

WHITWORTH, M.J. [M.P.?] and RANKIN, A.H., 1989a, Fluid inclusion geothermometry of lithium-bearing pegmatites associated with the Leinster Granite of S.E. Ireland (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 92. Authors at Dept. Geol., Imperial College, London, UK.

Four bedrock occurrences of spodumene-bearing granitic pegmatites intruded along or close to the margin of the Leinster Granite of SE Ireland at Aclare, Monaughrim, Moylisha and Stranakelly have been investigated using FI and stable isotope geothermometry.

Generally, pegmatites rich in Li phases usually contain abundant, well developed aqueous and CO_2-rich inclusions; however, the latter are absent in the Leinster pegmatites. Nevertheless, through detailed petrographic and thermometric work, it has been possible to elucidate the fluid regimes present during the evolution of the Leinster pegmatite system based on scarce aqueous inclusions hosted solely by quartz crystals up to 25 cm in length. Three types have been recognized: (1) L + V(aq), 5-10 μm, Th = 150-400°C, salinity = 0-1 wt % NaCl eq.; (2) L + V(aq), >8 μm, Th = 150-250°C, salinity = 5- >20 wt % NaCl eq.; and (3) L(aq), <2 μm, no thermometric data generated.

Trails containing type 1 inclusions are cut by those containing type 2 inclusions, but the relationship of type 3 inclusions is unknown. Isochores generated from type 1 inclusion model fluids containing 5 and 10 wt % NaCl eq. and Th of 250 and 400°C are compatible with a late-stage magmatic/early hydrothermal origin for the type 1 FI which are considered therefore as representative of the fluid phase from which the pegmatites crystallized. Combined isochore modelling, stable isotope and alkali geothermometry indicate that the pegmatitic fluid was generated in the final stages of crystallization of the Leinster Granite at 700°C and 2.6 kb (= 7-8 km depth in the crust). Crystallization in the petalite field was restricted to simple quartz-feldspar-muscovite (i.e., barren) pegmatites. However, at <460°C, spodumene crystallized down to 250°C. Phase relationships indicate a minimum P of 1.8 kb in the system. FI and stable isotope studies also preclude the involvement of meteoric waters during the crystallization of the pegmatites. A metamorphic fluid, represented by type 2 inclusions, may have been responsible for the alteration of spodumene to albite and muscovite. (Authors' abstract)

WHITWORTH, M.P. and **RANKIN, A.H.**, 1989b, Diverse fluid phases associated with the crystallisation and alteration of lithium pegmatites at Moylisha and Stranakelly, SE Ireland: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 769-772. Authors at Dept. Geology, Imperial College, London, U.K.

Mineralogical, fluid inclusion and stable isotope studies of Li pegmatites associated with the Leinster Granite of SE Ireland suggest that at least two significant fluid phases have interacted with the pegmatites at various stages during their evolution. Both mineralised and barren pegmatites crystallised from a late magmatic/early hydrothermal fluid exsolved from the crystallising Leinster Granite magma at around 675°C and 2.7 kbar (8.5 km depth) containing ~10 eq. wt % NaCl with a $\delta^{18}O$ value of ~+10.8‰ and cooled isobarically through the spodumene stability field down to ~250°C. A post-intrusion influx of fluids derived from basin dewatering, dehydration reactions and/or fluid-rock interactions in the surrounding metavolcanics caused spodumene in the pegmatites to be altered to Li-poor muscovite. (Authors' abstract)

WHITWORTH, M.P. and **RANKIN, A.H.**, 1989c, Evolution of fluid phases associated with lithium pegmatites from SE Ireland: Mineral. Mag., v. 53 (Part 3), (371), p. 271-284.

A longer version of previous paper. (E.R.)

WICKHAM, S.M. and **PETERS, M.T.**, 1989, Fluid transport properties of metamorphic lithologies revealed by oxygen isotopic mapping in the East Humboldt Range of northeast Nevada (abst.): Eos, v. 70, p. 1376.

WIECHMANN, M.J. and **FISHER, G.W.**, 1989, Infiltration metasomatism in systems with channeled fluid flow (abst.): Eos, v. 70, p. 495.

WIENS, R.C., **LAL, D.** and **CRAIG, H.**, 1989, Helium and carbon isotope ratios in Indian diamonds (abst.): Eos, v. 70, p. 1411-1412.

WILCOX, W.R., 1989, Transport phenomena in crystal growth from solution: 7th Int'l Summer School on Crystal Growth (ISSCG-7), August 26-31, Yamagata, Japan (30 pp. + 95 references). Author at Center for Development of Commercial Crystal Growth in Space, Center for Advanced Materials Processing, Clarkson Univ., Potsdam, NY 13676.

This is a review of the role of transport phenomena in crystal growth from solution. Transport phenomena are normally taken to include fluid motion (convection), heat transfer and mass transfer. These processes strongly influence growth rate, crystal morphology, and defect formation.

Mass transfer arises primarily from concentration gradients, but can also be caused by a T gradient (Soret effect), an electric field, acceleration or gravity, etc. In solutions, mass transfer is strongly enhanced by convection; the motion of the solution carries material with it. Similarly, convection can be caused by a variety of driving forces: a P gradient, mechanical forces, buoyancy, electric fields, and even the growth of the crystal itself. Except in liquid metals, heat transfer in liquids is also strongly enhanced by convection.

It is important to realize that the simple form of Fick's first law is often not valid in crystal growth from solutions, i.e., the mass transfer flux is not necessarily equal to the product of a concentration gradient and a diffusion coefficient. In multicomponent systems the flux of a component depends on the concentration gradients of all the other constituents. It is possible for a component to move from a region where its concentration is low to a region where its concentration is high. If the component is charged, its movement is also strongly influenced by an electric field, which may be generated by the diffusion process itself. The flux of a solute into the surface of the crystal equals the growth rate, and includes a contribution caused by the movement of the solution toward the crystal surface. This convective contribution has the effect of increasing the growth rate beyond that predicted by Fick's first law, especially when the solubility is large.

It is also important to note that the stagnant film model for heat and mass transfer in the presence of convection is a fiction and can lead to erroneous predictions. There is *no* unstirred layer near the surface of the crystal. With convection, the mass transport rate is *not* proportional to the diffusion coefficient and the heat transfer rate is *not* proportional to the thermal conductivity.

The operational challenge in crystal growth from solutions is to maximize the growth rate without trapping the solution as inclusions in the crystal. Constitutional supercooling is always present in solution growth, but does not prevent growth without interface breakdown. High quality crystals can be grown from solutions because step propagation is faster than step generation, as manifested by the presence of facets. Faceted growth can become unstable when step trains decelerate, which occurs when steps begin in regions of high supersaturation and move to regions of low supersaturation. In order to avoid this condition, either crystals must be grown very slowly or well-controlled vigorous convection must be used. However, if one desires to avoid inclusion formation in the transition from dissolution to growth, it is advantageous to grow in the absence of convection so that the transition from dissolution to growth may be made gradual. (Author's abstract)

WILDE, A.R., MERNAGH, T.P, BLOOM, M.S. and **HOFFMANN, C.F.**, 1989, Fluid inclusion evidence on the origin of some Australian unconformity-related uranium deposits: Econ. Geol., v. 84, p. 1627-1642. First author at BHP-Utah Minerals, P.O. Box 619, Hawthorn, Victoria 3122, Australia.

Fluid inclusions in altered and unaltered host rocks and hydrothermal quartz, calcite, and dolomite from the unconformity-related U deposits of Koongarra, Nabarlek, and Jabiluka (Northern Territory, Australia) were examined using standard microthermometry, laser Raman microprobe, and scanning electron microscopy. Decrepitated gases were analyzed in a mass spectrometer. The relationship of fluid inclusions to alteration and mineralization was established by occurrence restricted to the alteration zones around the deposits and the presence in fluid inclusions of solid phases which also occur as megascopic phases in the alteration.

S, halite-saturated fluid inclusions in altered host-rock quartz and in early hydrothermal quartz veins are believed to relate to hydrothermal alteration associated with ore deposition. These inclusions are identical to P inclusions in silicified and boron-metasomatized Kombolgie Formation sandstone above the Jabiluka 2 deposit (Durak et al., 1983) and hence sample post-Kombolgie fluids. The trapped fluid is saline and Ca rich (ca. 23 eq. wt % $CaCl_2$) and sulfate poor ($SO_4^{-2} < 0.001$ m). No gases were detected in the vapor phase of such inclusions and the median Th is 140°C. P inclusions in postore dolomite veins and S inclusions in host rock and hydrothermal quartz sample postore hydrothermal fluid. This fluid is hypersaline and also Ca rich (typically 35 eq. wt % $CaCl_2$) and is saturated with as many as 11 solid phases, including dolomite and iron-rich chlorite. Vapor bubbles in these inclusions contain methane and minor N_2 and the median vapor disappearance T is 127°c. Aromatic hydrocarbons detected by mass spectrometry are possibly related to this population.

The calcic brines are thought to have been terrestrial in origin and derived from the oxidized red-bed sediments overlying the deposits (MacArthur basin). Ore deposition was a response either to reduction of the ore-bearing fluid by direct interaction with graphite and ferrous iron in the wall rocks or by mixing with a methane and higher hydrocarbon-bearing brine, represented by postore fluid inclusions. Ore deposition and related hydrothermal alteration occurred between 200° and 300°C under a depth of cover of ca. 2 km. This T is consistent with independent T constraints and suggests an anomalous thermal gradient during ore formation. (Authors' abstract)

WILKINSON, J.J., 1989, Spatial and temporal aspects of Hercynian fluid evolution in southwest Cornwall (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 93-94. Author at Dept. Geol., The Univ., Highfield, Southampton, UK.

Crustal fluid evolution during the Hercynian orogeny in southwest Cornwall has been investigated to evaluate the contribution of metamorphism, deformation and magmatism to the genesis of the complex polymetallic mineralization observed in the province.

Detailed structural analysis of a 10 km coastal section extending from the Tregonning granite to the Lizard Boundary Fault has defined a vein chronology which constrains spatial and temporal variations in the fluid P-T-X throughout c.80 Ma of crustal evolution. A summary of the main tectonic stages and important features of the associated fluids is given below:

Metamorphism	Deformation	Fluids
Regional 350°C, ?3kb dehydration	Low-angle thrusting and nappe formation	H_2O-NaCl, T_h120-240°C. Salinity 1.4-3.9 wt. % NaCl eq.. Fluid internally buffered by wallrock.
Retrogressive. 300-200°C 2.5-1.0kb. minor rehydration.	Brittle imbricate thrusting.	H_2O-NaCl (-CO_2), T_h 120-270°C salinity 1.4-3.9 wt. % NaCl eq. Fluid internally buffered by wallrock.
Contact 600-200°C 1.5-1.0kb dehydration.	Vertical compression radial stretching.	CO_2-H_2O (-CH_4)-NaCl-KCl, T_h 200-440°C. Salinity 0-15 wt. % NaCl eq.. Fluid internally buffered by wallrock?
Retrogressive (hydrothermal) 400-150°C 1.0-0.5kb.	Jointing, normal faulting.	H_2O (-CO_2-CH_4)-NaCl-KCl-$CaCl_2$-$MgCl_2$ and H_2O-NaCl,T_h 350-150°C, salinity 0-35 wt. % NaCl eq. Extensive fluid rock disequilibrium.
None.	Wrench faulting.	H_2O-NaCl-$CaCl_2$ (-KCl), T_h 90-150°C salinity 17-26 wt. % NaCl eq.Fluid externally buffered.

Fluids associated with the contact metamorphism are believed to be of particular importance to the genesis of the early Sn-W mineralization. Early, dense CO_2-rich fluids (0.7-1.0 g cm^{-3}) were succeeded by an essentially H_2O-CO_2-NaCl fluid which began unmixing at ~1000 bars, 420°C, to produce low density CO_2 (-CH_4) vapor and moderately saline H_2O-NaCl (-KCl) liquid. This unmixing process displays a T zonation around the Tregonning granite stock. The occurrence of these fluid types in contact metamorphic veins as well as in pegmatite quartz and early tourmaline greisen veins indicates close interaction between metamorphic and magmatic processes in generating a mineralizing fluid which was subsequently incorporated into the meteoric water dominated hydrothermal system. (Author's abstract)

WILLIAMS, A.E., 1989, Reservoir fluid chemical and stable isotopic variations in active geothermal systems: Indicators of evolution and dynamics (abst.): Eos, v. 70, p. 1378.

WILLIAMS, A.E. and McKIBBEN, M.A., 1989, A brine interface in the Salton Sea Geothermal System, California: Fluid geochemical and isotopic characteristics: Geochim. Cosmochim. Acta, v. 53, p. 1905-1920.

Data from 71 geothermal production intervals in 48 wells from the Salton Sea Geothermal System (SSGS) indicate that fluids in that system cluster into two distinct populations in terms of their salinity and their stable isotopic compositions. The distinctive, hot, hypersaline brine (typically >20 wt %) total dissolved solids) for which the SSGS is known is overlain by a cooler (<260°C) fluid with distinctly lower salinity (typically <10 wt % total dissolved solids). The fluid interface typically cross-cuts sedimentary bedding but is consistently found where reservoir T are ~260°C. At these T, hypersaline brines have densities of ~1.0 gm/cm^3, while the low TDS fluids have densities as low as 0.85 gm/cm^3. This stable, density-stratified interface acts as a barrier to convective heat and mass transfer in the SSGS, isolating the hypersaline reservoir from overlying dilute fluids. A lithologic "cap" implied by previous SSGS models is unnecessary in such a stratified system since heat and mass transfer across the interface must occur by slow conductive, diffusional and interface mixing processes regardless of local permeability. (From authors' abstract by E.R.)

WILLIAMS-JONES, A.E. and **FERREIRA, D.R.**, 1989a, Fluid inclusion studies and the origin of cupriferous calc-silicate hornfelses at Patapedia, Gaspé, Quebec *in* Current Research, part B, Geol. Surv. Canada, Paper 89-1B, p. 83-92. Authors at Dept. Geological Sciences, McGill Univ., Montreal, Quebec H3A 2A7, Canada.

The factors responsible for the formation of cupriferous calc-silicate hornfelses in the Patapedia thermal zone are re-evaluated after study of fluid inclusions in quartz phenocrysts of synchronous felsic dykes.

Three distinct fluid inclusion types are recognized: a low to moderate salinity, high density aqueous fluid (Type I); a low density CO_2-rich fluid (Type II); and a high salinity, high density aqueous fluid (Type III). Types I and II predominate, whereas Type III inclusions form <10% of the population. All three types are interpreted to have been present during prograde metamorphism. Estimated T and P of metamorphism are 450° to 500°C and 700-1000 bars, respectively.

A model is proposed in which the metamorphism was caused by heat transferred from a low to moderate salinity fluid of partly orthomagmatic origin. On cooling and migrating to higher levels, this fluid evolved, first by dissolving H_2O/CO_2 produced by metamorphic reaction and later, by exsolving a high salinity aqueous fluid. The bulk of the metamorphism occurred at P-T conditions at which aqueous and CO_2-rich fluids were largely immiscible. Cu mineralization accompanied retrograde metamorphism at temperatures below 400°C and resulted from falling T and/or increased pH from CO_2 effervescence. (Authors' abstract)

See also following item. (E.R.)

WILLIAMS-JONES, A.E. and **FERREIRA, D.R.**, 1989b, Thermal metamorphism and water-carbon dioxide-sodium chloride immiscibility at Patapedia, Quebec: Evidence from fluid inclusions: Contrib. Mineral. Petrol., v. 102(2), p. 247-254.

See previous item. (E.R.)

WILLIAMS-JONES, A.E., **SAMSON, I.M.** and **LINNEN, R.L.**, 1989, Fluid evolution and its role in the genesis of the granite-related Madeleine copper deposit, Gaspé, Quebec: Econ. Geol., v. 84, p. 1515-1524. First author at Dept. Geological Sciences, McGill Univ., Montreal, Quebec H3A 2A7, Canada.

The Madeleine Cu deposit is hosted by biotite hornfels adjacent to the McGerrigle granitic complex, Quebec, and consists of stockwork orebodies, outwardly zoned from bornite-chalcopyrite to chalcopyrite-pyrrhotite. The mineralization predated the peak of contact metamorphism and is associated with biotite and calc-silicate vein and alteration assemblages. Chlorite-muscovite alteration and quartz-carbonate veins postdated mineralization.

Vein quartz contains low- and high-salinity aqueous and CO_2-CH_4 aqueous and nonaqueous fluid inclusion types. Isochore projections suggest that the deposit formed at 400° to 600°C and 1 to 2 kbars. Low ice-melting and eutectic T indicate that some aqueous inclusions have high Ca contents.

A model has been developed for the fluid evolution in which interaction of high-salinity orthomagmatic fluids with organic-rich shales produced CH_4/N_2-rich fluids and caused biotite alteration. Locally, the orthomagmatic fluids interacted with calcareous beds, releasing CO_2 and increasing their Ca content. The latter subsequently caused calc-silicate alteration. Chlorite-muscovite alteration and quartz-carbonate veining were caused by lower salinity fluids derived largely from formational waters. Outwardly decreasing water/rock ratios, which produced corresponding decreases in T and/or Cu/Fe and/or increases in aH_2S, are invoked to explain the observed zonation in sulfide mineralogy. (Authors' abstract)

WILLIAMS-JONES, A.E. and **SEWARD, T.M.**, 1989, The stability of calcium chloride ion pairs in aqueous solutions at temperatures between 100 and 360°C: Geochim. Cosmochim. Acta, v. 53, p. 313-318. First author at Dept. Geol. Sci., McGill Univ., Montreal, Quebec, Canada.

The speciation of calcium in chloride solutions has been investigated between 100 and 360°C by measuring the solubility of AgCl in HCl-$CaCl_2$ solutions in which chloride varies from 0.3 to 3.0 m and calcium is maintained constant at 0.1 m. Cumulative equilibrium formation constants of calcium chloride ion pairs were evaluated using a non-linear least squares procedure. Association constants could not be evaluated for calcium chloride ion pairs from the data at 100°C. However, at 150°C the cumulative formation constants for $CaCl^+$ and $CaCl_2^0$ are 0.85 and 1.73, respectively. The stability field for $CaCl^+$ decreases with increasing T, whereas that for $CaCl_2^0$ increases sharply and at

360°C K_2 is 4.95 • 10^4. Higher order calcium chloride ion pairs either do not form or have stability fields too small to be detected by the methods used in this study.

The neutral aqueous calcium chloride ion pair $CaCl_2^0$ contributes significantly to calcium speciation in intermediate to high salinity hydrothermal solutions: at 250°C, 50 mol % of the calcium in a 1 m HCl solution occurs as $CaCl_2^0$. The effect of this ion pairing is to increase the pH stability limits and solubilities of calcium-bearing minerals in such solutions. (Authors' abstract)

WILLIS, M.A., CAMPBELL, A. and **PHILLIPS, Randy,** 1989, High salinity fluids associated with allanite mineralization, Capitan Mountains, New Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A287. First author at Dept. Earth and Planetary Sciences, Washington Univ., Campus Box 1169, St. Louis MO 63130.

The Capitan pluton, the largest Tertiary stock in New Mexico, is a compositionally and texturally zoned granitic pluton. Numerous quartz veins occur on its flanks. The Mina Tiro Estrella prospect located on the southern flank of the east-west trending pluton is the most mineralized and best exposed vein in the area. The vein contains quartz, adularia, sphene, and allanite and is currently producing Japanese-law twinned quartz and allanite crystals for mineral collectors. Preliminary electron microprobe data on the sphene and allanite reveal that these minerals host an assortment of elements such as Ti, Nb, Ce, La, and F. Electron backscattered images show that both sphene and allanite have complex zonation.

Fluid inclusions are abundant in the quartz crystals. Microthermometry was performed on 80 inclusions. The majority of the measured inclusions range in size from 20 to 40 μm. Although the inclusions were trapped over a period of time (as suggested by their P, PS and S origins), they all possess the following characteristics:

(1) Inclusions contain numerous dms. On average inclusions contain eight dms, although up to 15 have been noted in a single inclusion. The minerals have been identified tentatively by optical properties, heating behavior and SEM energy dispersive analysis. These minerals are halite, sylvite, anhydrite, hematite, sphene, calcium chloride, and opaque oxides.

(2) Modeling the inclusion fluids after the KCl-NaCl system, a corresponding salinity averaging 56 eq. wt % NaCl and 19 eq. wt % KCl was found for the measured inclusions.

(3) Th range from 470-620°C with the majority of the inclusions homogenizing above 550°C. Homogenization is by halite disappearance. No S inclusions which trapped a lower-T and lower-salinity (and presumably later) fluid were observed. Inclusions in sphene and adularia are difficult to observe; however, those seen appear similar to those found in the quartz.

The high salinity, high T of homogenization and close proximity to the Capitan stock suggest a magmatic origin for the mineralizing fluid. Preliminary stable isotope results support the magmatic origin of the fluid. (Authors' abstract)

WILSON, P.N. and **PETERSEN, E.U.,** 1989, Fluid inclusion evidence for fluid mixing in the Oxec Cyprus-type copper deposit, Guatemala: Econ. Geol., v. 84, p. 444-449. Authors at Dept. Geology and Geophysics, The Univ. Utah, Salt Lake City, UT 84112.

FI measurements were made on six samples from mineralized quartz which vein the altered and brecciated lower pillow basalt unit. P, PS, and S FI were identified in the quartz using the criteria of Roedder (1984). Most salinity values were 3-4.5% NaCl eq. %, but some ranged up to 8.5%. Th ranged from ~220 to 325, with most in the 280-320 range. No evidence of CO_2 or $CaCl_2$ was found.

These data suggest that variations in T and salinity existed during the formation of the mineralized basalt-quartz and quartz veining. Four possible explanations for this variation are (1) mixing of the saline fraction of a boiled hydrothermal fluid with its seawater parent, (2) mixing of high-salinity pore fluids with seawater, (3) mixing of seawater-salinity hydrothermal fluids with a high-salinity magmatic water, or (4) interaction of a hydrothermal fluid with an evaporite sequence. (From authors' text by E.R.)

WILSON, W.R. and **KYSER, T.K.,** 1989, Stable and radiogenic isotope tracing of fluids in epithermal gold mineralization in the Little Rocky Mountains, Montana (abst.): Atlantic Geology, v. 25, p. 217. First author at Dept. Earth Sci., Memorial Univ. Newfoundland, St. John's, Newfoundland A1B 3X5, Canada.

The Little Rocky Mountains, Montana, are a result of doming of Archean basement gneisses and Phanerozoic sedimentary rocks produced by the emplacement of a quartz monzonite to syenite intrusive complex of Early Tertiary age. The intrusive rocks have whole-rock $\delta^{18}O$ values near 8 and initial $^{87}Sr/^{86}Sr$ ratios from 0.7050 to 0.7061. The Zortman and Landusky mining areas in the Little Rockies produce Au from fracture systems filled with clay minerals and low concentrations of Au-bearing pyrite. K-Ar ages of illites associated with the Au mineralization are near 60 Ma and are similar to K-Ar and fission-trace ages of the intrusive rocks. δD and $\delta^{18}O$ values of these illites indicate that they, and the Au-bearing pyrite, formed at T near 250°C from meteoric fluids having $\delta^{18}O$ values near 1 and δD values near -80. This Au event is characterized by illites having much higher initial $^{87}Sr/^{86}Sr$ ratios (as high as 0.7784) than the intrusive rocks that host the fracture system, suggesting that Sr, and by inference the Au, most likely were derived from Precambrian basement gneisses.

After the Au was emplaced, later fluids released the Au by oxidizing the pyrite and formed kaolinite and hydrothermal fluorite and dolomite, the latter of which are characterized by $^{87}Sr/^{86}Sr$ ratios near 0.708, similar to those of the intrusive rocks and Phanerozoic carbonates. Low salinity fluid inclusions in fluorite have Th = 100 to 200°C and have $\delta^{18}O$ values near -10 and δD values near -110, consistent with those of Tertiary ground waters. $\delta^{34}S$ values of pyrite do not correlate with Au contents, and their wide variation from -11.4 to 6.3 cannot be used to distinguish among igneous, sedimentary and metamorphic sources. (Authors' abstract)

WOJCIK, K.M., GOLDSTEIN, R.H. and **WALTON, A.W.,** 1989, Fluid migration and thermal history recorded in diagenetic phases of Pennsylvanian sandstones and limestones, SE Kansas (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A4. Authors at Dept. Geology, The Univ. of Kansas, Lawrence, KS 66045.

It is now well known that migration of warm fluids through the Ouachita foreland was responsible for formation of Mississippi Valley-type (MVT) deposits in Cambro-Ordovician and Mississippian carbonates of the US Midcontinent. Overlying Pennsylvanian shales, limestones, and sandstones contain a complex sequence of diagenetic phases, including some ore minerals. This study documents the diagenetic conditions of this overlying section to provide a better understanding of the history of foreland areas, of which ore deposition is a part.

Limestones and sandstones experienced three stages of diagenesis. The sequence in limestones includes an early stage with zoned calcite and formation of moldic and vuggy pores; and intermediate stage with fracturing, iron-rich calcite, authigenic quartz, and sparse sphalerite; and a late stage with formation of vuggy pores, precipitation of baroque Ca-Fe-dolomite and kaolinite, and introduction of oil. Paragenesis in sandstones begins with early stage pyrite, Fe-calcite, and siderite; then syn-compactional cementation by quartz overgrowths in the intermediate stage; and multiple phases of framework grain dissolution, precipitation of barite (minor), baroque Ca-ankerite and kaolinite, and oil introduction during the late stage. Similarity of the intermediate and late stages of diagenesis in both lithologies suggests regional controls. Conversely, late carbonate cements in sandstones and limestones show systematic differences, including chemical and isotopic composition and zoning patterns, that may reflect stratigraphic or lithologic effects or formation at different times.

Th of P fluid inclusions from late Ca-Fe-dolomites and Ca-ankerites indicate precipitation or reequilibration over a range of T from 90 to at least 150°C, which is well above normal burial T. Salinity ranges from 20 to 25% NaCl eq. T data suggest regional heating and thus relate diagenesis broadly to the migration of warm fluids, which led to formation of MVT deposits of the Midcontinent. MVT deposits and the diagenetic record in the Pennsylvania strata provide complementary information about the regional processes in the Ouachita foreland. (Authors' abstract)

WOLFF, J.A., PETERSON, A., and **TURBEVILLE, B.N.,** 1989, Mixing dynamics of carbonatite and silicate magmas: Implications for the origin of natrocarbonatites (abst.): Eos, v. 70, p. 1417.

WOOD, B.J. and **VIRGO, David,** 1989, Upper mantle oxidation state: Ferric iron contents of lherzolite spinels by ^{57}Fe Mössbauer spectroscopy and resultant oxygen fugacities: Geochim. Cosmochim. Acta, v. 53, p. 1277-1291.

WOOD, S.A., 1989a, Raman spectroscopic determination of the speciation of ore metals in hydrothermal solutions: I. Speciation of antimony in alkaline sulfide solutions at 25°C: Geochim. Cosmochim. Acta, v. 53, p. 237-244.

WOOD, S.A., 1989b, The forms of transport of the REE and Y in hydrothermal solutions (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-21. Author at Dept. Geol. Sci., McGill Univ., 3450 University St., Montreal, PQ, H3H 2A7, Canada.

Much recent evidence suggests that the REE may be mobile in hydrothermal solutions during a variety of geological processes. The mobility of the REE during fluid-rock interaction is of special concern to those wishing to use these elements as petrogenetic indicators and those wishing to explain the origin of a variety of presently or potentially economic REE occurrences.

The predominant oxidation state of the REE in aqueous solutions at room T is the +3 state (with the exception of Ce and Eu, which may exhibit the +4 and the +2 state, respectively). The charge and the size of these ions dictate that they form strongest complexes with the so-called hard ligands such as fluoride, hydroxide, sulfate, phosphate and carbonate. Chloride complexes may also be important due to the predominance of chloride as a ligand in nature. All these complexes are known at room T and thermodynamic data is available with which to evaluate their stability. A variety of diagrams will be presented to illustrate the predominant complex stoichiometries at room T under various conditions of pH and ligand activity.

Surprisingly, in spite of the recent interest in the hydrothermal transport of REE, very little experimental data exists on their speciation at high T. Therefore, the existing body of low T data has been used as a basis to make predictions about the behavior of the REE at higher T using the techniques of Helgeson and coworkers. Preliminary results suggest that hydrolysis becomes increasingly important for these metals while available ligands such as F^-, Cl^-, SO_4^{2-} and CO_3^{2-} become increasingly associated with H^+ and other cations so that hydroxide complexes may predominate under hydrothermal conditions. The ranges of conditions under which the various species predominate will be presented and discussed. (Author's abstract)

WOOD, S.A. and **MOUNTAIN, B.W.**, 1989, The hydrothermal transport of platinum and palladium: Thermodynamic constraints revisited (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-79.

WOOD, S.A., MOUNTAIN, B.W. and **FENLON, B.J.**, 1989, Thermodynamic constraints on the solubility of platinum and palladium in hydrothermal solutions: Reassessment of hydroxide, bisulfide, and ammonia complexing: Econ. Geol., v. 84, p. 2020-2028.

WOOD, S.A. and VLASSOPOULOS, Dimitrios, 1989, Experimental determination of the hydrothermal solubility and speciation of tungsten at 500°C and 1 kbar: Geochim. Cosmochim. Acta, v. 53, p. 303-312.

WOOD, S.A., VLASSOPOULOUS, D. and **KRANIDIOTIS, P.**, 1989, The volatility of high technology (Li, Be, Ga, Ge, REE, Nb, Ta) and related metals in magmatic systems: Applications to ore formation (abst.): GAC/MAC Program with Abstracts, v. 14, p. A-32.

WOPENKA, Brigitte, PASTERIS, J.D. and **FREEMAN, J.J.**, 1989a, Analysis of individual fluid inclusions by micro-FTIR and micro-Raman spectroscopy: Advantages and disadvantages (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 71. First author at Dept. Earth and Planet. Sci. and McDonnell Center for Space Sci., Washington Univ., Campus Box 1169, One Brookings Drive, St. Louis, MO 63130.

Micro Fourier transform infrared (μ-FTIR) spectroscopy and laser Raman microprobe (LRM) spectroscopy are the only two nondestructive analytical techniques that can yield direct information on individual inclusions. The two techniques have in common that (1) the vibrational spectrum is used to identify components and to quantify fluid mixtures, (2) in principle, solid, liquid and gaseous inclusions can be analyzed in situ in a mineral matrix, (3) ionic species and noble gases cannot be detected, and (4) the quantification of multicomponent FI requires knowledge of the absorption/scattering efficiencies of individual components. In the last 10+ years, LRM spectroscopy has been shown to be a very powerful method for the study of fluid and solid inclusions. In contrast, µ-FTIR spectroscopy is a relatively new technique, whose potential for the analysis of geological samples is still under investigation. The analytical characteristics that determine the advantages and/or disadvantages and limitations of the µ-FTIR and LRM techniques, respectively, are due to differences in the physical principles (absorption vs. scattering), the selection rules (change in dipole moment vs. change in polarizability), the kind of light source used (polychromatic black body source: 1-200 µm vs. monochromatic continuous gas laser, e.g., 514 nm), and thus the spatial resolution (~30 µm vs. ~2-3 µm).

Clearly, no single technique is going to fulfill all micro-analytical needs. Two of the major limitations of the LRM technique are that (1) conjugated double bonds (e.g., cyclic hydrocarbons) cause fluorescence, which commonly makes it impossible to get Raman spectra of hydrocarbon FI and (2) molecular water has a very broad (several hundreds of cm^{-1}) Raman band, which makes its quantification in FI difficult, even though its Raman scattering efficiency is several times that of CO_2. The limitations of µ-FTIR spectroscopy are mainly determined by sampling geometry (transmission technique: everything in beam path--inclusion(s), matrix, atmosphere--is analyzed) and the wavelength of light whose interaction with the sample is being studied (2.5 µm to 25 µm for mid-IR). Diffraction constraints require that the size of the aperture image at the sample plane not be smaller than about 20 x 20 µm in µ-FTIR analysis. Due to stray light effects, this aperture size in turn constrains the minimum inclusions cross-sectional area to be about 200 μm^2.

We will present results from systematic µ-FTIR tests on several different geologic samples to show that the IR-absorption of fluid species depends on parameters such as inclusions size, inclusion shape, ratio of aperture size to inclusion size (must not exceed ~2), nature of species in inclusion, density of species, and matrix effects. The ability to obtain quantitative information from µ-FTIR studies on FI will depend on both the similarity of these parameters in unknowns and standards and on the reproducibility of instrumental parameters, such as the condenser focus.

In general, we conclude that µ-FTIR analysis is not a panacea for the problems experienced in LRM analysis of FI. The LRM can identify and quantify the contents of much smaller FI (≤3 µm), even aqueous inclusions, than can the µ-FTIR technique; the LRM can detect homonuclear species like H_2, O_2, and N_2, which are not IR-active. The most significant potential advantage of µ-FTIR is its ability to analyze fluid volumes consisting of more than one phase, e.g., CO_2 and H_2O phases, which in principle would permit bulk fluid analysis in inclusions of sufficient size. The quantitativeness of µ-FTIR analysis is still under investigation. (Authors' abstract)

WOPENKA, Brigitte, PASTERIS, J.D. and **FREEMAN, J.J.**, 1989b, Detection of water in individual fluid inclusions by micro-infrared and micro-Raman spectroscopy (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A286. First author at Dept. Earth and Planetary Sciences, Washington Univ., St. Louis, MO 63130.

A major concern in fluid inclusion research is the detection and quantification of H_2O in individual volatile-bearing inclusions in which an aqueous phase may or may not be visible. Water is known to be a strong IR absorber and a weak Raman scatterer, which leads to the common belief that IR spectroscopy is the better method to detect H_2O in fluid inclusions. Detectability is determined by inclusion size, as well as the concentration and density of the aqueous phase. In our experience, for fluid inclusions <~200 μm^2 in cross-section, only Raman spectroscopy can detect H_2O. For instance, excellent Raman spectra can be obtained on 2.5x2.5 µm brine inclusions. However, due to the pinpoint nature of the micro-Raman technique (excitation volume several μm^3), it cannot provide bulk analysis of two-phase inclusions. In principle, micro-IR has the potential to provide bulk compositions on sufficiently large two-phase inclusions. However, both upper- and lower-bound constraints on inclusion size complicate quantitative IR analysis. The lower bound is determined mainly by the diffraction-limited size of the aperture required for IR analysis of inclusions. The upper bound is controlled by total absorption of the IR radiation, which is a distinct possibility for liquid inclusions > several µm thick. Since most inclusions are thinner at their edges than at their centers, IR transmission still may occur through the edges of inclusions whose cores are IR-opaque. This selective sampling will be most serious for two-phase inclusions, especially for those containing water, because water always wets the walls. Given the size range of inclusions commonly of interest to petrologists, Raman spectroscopy appears to be the more applicable of the two techniques. (Authors' abstract)

WRIGHT, J.H. and KWAK, T.A.P., 1989, Tin-bearing greisens of Mount Bischoff, northwestern Tasmania, Australia: Econ. Geol., v. 84, p. 551-574. First author at Mt. Kersey Mining, 44 St. Georges Terrace, Perth, Western Australia.

The large Mount Bischoff Sn deposit occurs within an inlier of Precambrian sedimentary rocks which are surrounded by lower Paleozoic and Tertiary sedimentary and volcanic rocks. Sn is contained within a network of altered Devonian porphyry dikes (endogreisens), replaced dolomite (exogreisen), mineralized hydrobreccias, thin veins, and alluvials.

Greisen-style alteration of porphyry dikes is zoned inward and downward from nearly fresh ß-form quartz + K-feldspar dike material through muscovite + fluorite ± tourmaline greisen and topaz + quartz greisen to quartz greisen. Sn grades of up to 2 wt % occur within endogreisen, with higher grades occurring near the topaz + quartz-quartz greisen contact.

Replacement of dolomite by greisen assemblages and greisen-style alteration of porphyry dikes were cogenetic. The mineral assemblages and the spatial distribution of greisen minerals, such as mica, topaz, and tourmaline, in endo- and exogreisens are similar. Topaz, quartz, fluorides, cassiterite, and tourmaline occur in endo- and exogreisen, although the proportion of fluoride minerals (sellaite and fluorite) is high where dolomite is replaced. Within exogreisens the highest grades of Sn occur at the contact between topaz-bearing endo- and exogreisens, grades obtained from drill core range up to 22 wt % (1.3-m intersection).

The greisens were overprinted by assemblages containing phyllosilicates (chlorite, talc, phlogopite, serpentine, phengite), carbonates (magnesite, siderite, dolomite), abundant sulfides (pyrrhotite ± pyrite, sphalerite), late fluorite, and later argillic alteration. Only limited quantities of dolomite were replaced by these later postgreisen assemblages.

Fluid inclusion T range from 90° to near 500°C, with the greisen being produced between ~340° to 420°C or higher and the later overprints at progressively lower T. Salinities at the greisen stage of mineralization were high, with measurements commonly between 30 to 40% total dissolved salts. Ca-Na-K-Fe-Mn chlorides, possible fluorides, CO_2, and hydrocarbons(?) were deduced as components of the fluid phase. Lesser amounts of dissolved Si, Al, and B and rare Ti, Ca, La, P, Sn, Cu, and S were inferred from dm identifications.

The deposit was formed from acidic and relatively reduced hydrothermal solutions in subvolcanic conditions, at a depth of ~1 km, above a leucogranite pluton (granite inclusions exist in the dikes). High-level brecciation was cogenetic with porphyry dike intrusion and both occurred in several separate intrusion-mineralization cycles. (Authors' abstract)

WU, Xin, BENY, Claire, ZIMMERMANN, J.L. and TOURY, J.C., 1989, Analyses of inclusion gases in gold-bearing lode quartz from Le Châtelet (Creuse, France): Comparison with the l'Auriéras (Haute-Vienne, France) gold deposit: C.R. Acad. Sci. Paris, v. 309, ser. II, p. 707-712 (in French, English abstract).

A comparative study of G-rich I in auriferous quartz from Le Châtelet and l'Auriéras has been performed using microthermometry, Raman microprobe analysis and mass spectroscopic analysis of volatiles extracted after heating and/or crushing. Higher CO_2/CH_4 ratios are noticed at l'Auriéras. At Le Châtelet, where Au is incorporated into arsenopyrite lattice, an inverse correlation between H_2 molar fraction and the CO_2/CH_4 ratio has been revealed. One suggests that As reduction, at the time of ore deposition, has been enhanced by local increase of fH_2, under non equilibrium conditions. (Authors' abstract)

XAVIER, R.P., BARBOSA, J.S.F., IYER, S.S., CHOUDHURI, Asit, VALARELLI, J.V. and CORDANI, U.G., 1989, Low density carbonic fluids in the Archean granulite facies terrain of the Jequié Complex, Bahia, Brazil: J. Geol., v. 97, p. 351-359. First author at Instituto de Geosciências-UNICAMP, Caixa Postal 6152, Campinas, SP, Brazil.

The 2.7 Ga old high-grade metamorphic rocks of the Jequié Complex of Bahia include charnockites, enderbites, and late pink potassic granites. Mineralogic P-T determinations for the granite terrain yield 4-5 kb/750-850°C for the peak of metamorphism. Microthermometry of fluid inclusions in quartz was performed on different rock types. Early CO_2-rich fluids have densities around 0.85 g/cm^3 and may represent synmetamorphic fluids, since the isochores cross the inferred P-T box. Late fluids are of lower density and correspond to the waning phase of metamorphism. The correspondence in the Jequié Complex of the relatively low P-T conditions with the low density CO_2-rich fluids provides evidence that the trapped fluids are to some degree representative of the granulite facies metamorphism, though they may have been modified by post-metamorphic processes. (Authors' abstract)

XIA, Yong, 1989, Probe into features of structures controlling a deposit, through fluid inclusions; taking Yangshikeng Hg-ore deposit in Sichuan Province as an example: Kexue Tongbao (Foreign Language Edition), v. 34(2), p. 173-174.

XIUJUAN, Ma, 1989, A study of the geochemistry of inclusions of the Dajishan tungsten ore deposit (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 72. Author at Inst. Min. Deposits, Chinese Acad. Geol. Sci.

This particular study more comprehensively synthesizes and elaborates on the main characteristics of inclusions from the Dajishan tungsten ore deposit, and provides a series of physical and chemical parameters for the ore-forming fluid in the deposit obtained through investigations on the inclusions by using the Th, Td, and freezing methods, as well as through the compositional analysis and studies of hydrogen and oxygen isotopes. The results of the study show the T of mineralization ranges largely within 238-328°C occasionally reaching as high as 375°C in maximum and as low as around 164°C in minimum. The salinity of the ore-forming fluid ranges from 4.4 to 9.5 (wt % NaCl), largely falling within 5-8 (wt % NaCl). The system of the composition of fluid is close to the $NaCl-H_2O-CO_2$ system. It is the H_2O in the form of steam that predominates among the volatile components, less CO_2, with minor H_2, CO and CH_4. Also, there is a tendency of gradual increase in the content of H_2O in the ore-forming fluid in the course from the early stage till the late stage of mineralization, which ranges from ~636-1089 mg/kg of samples. The density of the fluid calculated from Th and salinity ranges within 0.8-0.9 g/cm^3, while the results of analysis of hydrogen and oxygen isotopes tends to show that the δDH_2O in the ore-forming fluid of the particular deposit is of -52.5 to -57.89‰ and $\delta O^{18}H_2O$ + 2.4 to +3.9‰. The ore-formation P ranges largely from 43 Mpa to 100 Mpa, averaging about 60 Mpa. In addition to pH value in the tungsten-forming fluid determined according to the mineral associations in the deposit and derived from the corresponding formula is 5.34 to 5.41 or a bit higher with the medium showing a weakly acidic nature. The oxygen fugacity (fO_2), calculated from the gaseous species analysis and the derived ore-formation P and pH value is $\sim 10^{-25}$ Pa, the CO_2 fugacity (fCO_2), $\sim 10^{5.5}$ Pa and the Eh value of the oxidation-reduction potential is -0.6 to -1.3.

The tungsten mineralizations in the particular deposit are characterized by an obvious vertical zonation, with either the mineral associations or the Th and salinity of mineral inclusions showing a regular variation from the early stage till the late stage of mineralization. On the basis of the study of inclusions and isotopic analysis and of the comprehensive geological investigations, the author is of the opinion that the ore-forming fluid comes largely from a deep-seated magmatic source, occurring mainly in the form of "magmatic water," but the incorporation of rain water exerts some influence on the nature of the ore-forming fluids. The present paper puts forth also nine kinds of criteria and the direction for ore-prospecting, including the mineralization-related stratigraphic, tectonic and magmatic criteria, mineral associations, alterations of the country rocks, main salient features of inclusions as represented by Th, salinity, density and the environment of ore-forming medium, providing the clues and indications for searching for this type of ore deposit.

The particular study shows that the migration of mineralizing substances takes the form of complex of halogen elements, meanwhile the content of CO_2 in the fluid also influences to a certain degree on the tungsten mineralization. (Author's abstract)

YAMADA, Kazuo, 1989, Skarn forming processes at the Senno deposit, Nakatatsu mine, central Japan: J. Faculty of Science, Univ. Tokyo, Section II, v. 22, no. 1, p. 11-37. Author at Onoda Cement Co., Ltd. 1-1-7, Toyosu, Koto-ku, Tokyo, Japan.

The skarns in the Senno deposit of the Nakatatsu mine are mainly formed by the replacement of limestone and basic rock of the Fujikuradani Formation. Skarns show zonal distribution as follows [in order of increasing oxidation]: (1) skarns originating from limestone: wollastonite and/or bustamite skarn or diopsidic skarn, hedenbergitic skarn and andraditic skarn; (2) skarns originating from basic rock: epidote skarn and grossularitic skarn.

Chemical analysis of skarn minerals and FI studies clarified the skarn forming process. At an early stage, under conditions of ~500°C and high salinity of fluid (~50 wt % NaCl eq.), wollastonite and/or bustamite skarn and diopsidic skarn were formed. Diopsidic skarn mainly consists of diopside-molecule-rich clinopyroxene, grossular-molecule-rich anisotropic grandite garnet and calcite. Limited movements of elements occurred at this stage, indicated by the mode of occurrence. At a later stage, under conditions of ~370°C and low salinity of fluid (less than 8 wt % NaCl eq.), hedenbergitic skarn, which consists of hedenbergite-johannsenite-molecule-rich clinopyroxene, was formed. Large scale movements of elements occurred at this stage, indicated by large scale replacement. Following this stage, the redox state became more oxidizing at a similar T, and andraditic skarn was formed, which consists of andradite-molecule-rich isotropic garnet. Andraditic skarn replaced diopsidic skarn and hedenbergitic skarn, suggested by FI data and the relic texture of clinopyroxene of hedenbergitic skarn. The hedenbergite-johannsenite-molecule-rich clinopyroxene changed its chemical composition to diopside-molecule-rich during the replacement or mineralization. With the change of the redox state to an oxidizing one, sulfide mineralization began a similar formation T to that of the andraditic skarn, as indicated by FI data. (Author's abstract)

YAN, Junping and LIU, Ping, 1989, Geological features and genesis of the mercury deposits of Guizhou, *in* Yan Junping, ed., Geology of mercury deposits in Guizhou, China, p. 1-56.

Indexed under FI. (E.R.)

YANG, M.M., CRERAR, D.A. and IRISH, D.E., 1989, A Raman spectroscopic study of lead and zinc acetate complexes in hydrothermal solutions: Geochim. Cosmochim. Acta, v. 53, p. 319-326.

YAO, S.Z., TOURET, J.L.R. and JAHN, B.M., 1989, Fluid inclusions in granulites from the Eastern Hebei province, China (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 95. First author at Chengdu, China.

Ortho- and paragranulites from the Eastern Hebei province, China, contain high density CO_2-rich FI. CO_2 is most abundant in igneous granulites, notably in metatonalites which might have been emplaced during peak metamorphic conditions. In metasediments and in charnockites (*sensu stricto*), CO_2 inclusions are not only less abundant, but also of lower density. Only a few of the highest density CO_2 inclusions in the metatonalite might possibly represent remnants of peak metamorphic fluids. The other CO_2 inclusions have been re-equilibrated or introduced during the post peak metamorphic evolution, which corresponds to a simple "adiabatic uplift" P-T path (P decreasing more rapidly than the T).

These data are consistent with an introduction of CO_2 during the synmetamorphic intrusion of the tonalite, then its local redistribution amongst neighboring rocks after the peak metamorphism. (Authors' abstract)

YARDLEY, B.W.D., BANKS, D.A. and CAMPBELL, L.S., 1989, Chemical evolution of ore fluids from Cornwall, UK (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 96. Authors at Dept. Earth Sci., Univ. Leeds, UK.

Chemical analysis of inclusion fluids from vein quartz in the St. Austell and Cligga Head districts reveal some systematic patterns that can be related to ore precipitation. The highest T, barren veins with quartz, tourmaline ± topaz yield high levels of Fe, Mn and Zn and high K/Na ratios. Lower T veins contain lower levels of ore-forming elements but retain high Mn. We interpret this as a signature of the primary magmatic fluid component. Despite the overall high Mn-levels, Mn/Fe ratios show considerable variability, and this could reflect either sulphide scavenging by wall rocks, or boiling. Late stage fluids associated with kaolinization are chemically quite distinct, being more dilute, low in Mn and with high K/Na ratios. (Authors' abstract)

YARDLEY, B.W.D., BANKS, D.A., DAVIES, G.R. and McCAIG, A., 1989, Application of fluid inclusion analyses to tracing fluid evolution in a thrust belt (abst.): Geol. Soc. Am. Abst. with Programs, v. 21, p. A359. Authors at Dept. Earth Sciences, Univ. Leeds, Leeds LS2 9JT, U.K. [Note: Verbal presentation cancelled. (E.R.)]

Quartz veins from fractures developed in association with late-stage thrusting of the Gavarnie nappe, central Pyrenees, contain abundant inclusions of Na-Ca-Cl brines, with equivalent salinities in the range 15-25 wt % NaCl.

Broadly similar inclusions occur in veins hosted by Cretaceous and Triassic sediments and in low grade and high grade Hercynian basement slices.

Chemical analyses of major and trace elements using the improved crush-leach technique of Bottrell et al. yield a range of Na:Ca ratios and are charge-balanced with chloride as the dominant anion. The overall chemistry is indistinguishable from many oil field brine analyses, despite the relatively high T and the possibility of metamorphic fluid being present. Mg and K are low, while Br:Cl ratios (determined by ion chromatography) are higher than sea-water, like many such brines.

Age-correlated Sr and Pb isotope analyses from the inclusion fluids prove to be very close to those of adjacent wall rocks, and thus vary considerably between different veins in the thrust stack. An exception is a vein from granitic basement overlain by Triassic sediments, whose fluid has the Triassic sedimentary signature.

It is concluded that fluids in the thrust stack were brines derived from the sedimentary lithologies, and that these did not mix greatly. (Authors' abstract)

YARDLEY, B.W.D., BANKS, D.A., DAVIES, G.R., McCAIG, A.M. and **GRANT, N.T.**, 1989, Chemistry and isotopic composition of fluid from a deep thrust zone, Central Pyrenees: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 789-__. Authors at Dept. Earth Sciences, Univ. Leeds, Leeds, U.K.

During late stage Alpine thrusting of the Gavernie Thrust zone, Central Pyrenees, extensional fractures filled with quartz were formed. The veins contain abundant hypersaline brine inclusions with up to 25 wt % dissolved salts dominantly NaCl and $CaCl_2$. Na-dominated brines are closely associated with Triassic redbeds, Ca-dominated brines are associated with the Cretaceous limestones. Veins in the Silurian black slates and high grade Hercynian basement do not have distinctive fluid chemistries, instead the composition is identical to the closest sedimentary formation (Cretaceous and Triassic, respectively). Sr and Pb isotopic analysis of the fluids and host rocks confirms the distinctive fluid rock associations. K and Mg contents are low and the fluid chemistries are similar to oilfield brines; indeed organic traces are present. We conclude that fracturing in the thrust zone led to only local permeability enhancement and that the fluids were derived from the local sedimentary rocks without a significant input of either surface or metamorphic waters. (Authors' abstract)

YAROSHEVICH, V.S. and **AREVEDZE, D.V.**, 1989, Fluid inclusions and stable isotopes from skarn-iron ore deposits, USSR (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 97. Authors at Caucasian Inst. Min. Resources, Tbilisi, 380062, Georgia, USSR.

An integrated S, O, C & H isotope, and FI study utilizing microthermometry, and inclusion volatile and leachate analysis, has been undertaken on a number of skarn-Fe ore deposits.

The study indicates that the Fe mineralization occurred at a minimum of 300°C from deep seated magmatic fluids. Characteristically, these mineralizing brines have abnormally high levels of Fe (up to 40 g/l of H_2O). Ore metal precipitation was associated with dilution of the magmatic fluids with meteoric water. However, the source of S and C was magmatic even in the later fluids. Fe mineralization is post-dated by a quartz-calcite-sulphide association, formed <250°C from Na-Ca, Cl-sulphate fluids. Further dilution and cooling of the ore fluids resulted in the formation of barren quartz-calcite and zeolite veinlets. (Authors' abstract)

YE, Xin and **WANG, Lijuan**, 1989, A study on fluid inclusion and metallogenesis of a porphyry Cu-Mo deposit, Urugetu Hill, Inner Mongolia, China: Geology and Prospecting, v. 25(6), p. 14-21 (in Chinese).

YIN, Hanhui, 1989, A huge Pb-Zn deposit in western Yunnan Diwa region (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-410-411. Author at Academia Sinica, Changshan, Hunan, P.R.C.

This huge Pb-Zn deposit consists of a large bedded orebody concordant with the Paleogene and some small orebodies. The large one occurs in the Yulong formation of the Paleogene, associated with salt-bearing beds. It is several tens of meters in thickness and more than 1000 m in dip length. The ore could be divided into two kinds, sandstone hosted and breccia hosted. The major ore minerals are sphalerite, galena, pyrite, celestite, barite, gypsum, quartz, and calcite.

The sulfides in the deposit are enriched in S^{32}, with μS^{34} values ranging from -0.4 to -21.0(% [sic]). The average value is -17.4(%) for sandstone-hosted ore and -10.9(%) for breccia-hosted ore. Homogeneous lead isotopic composition is noticeable. They are similar to those of tholeiite from midocean ridges, indicating a deep-seated derivation from a homogeneous U-Th-Pb system. Results of the stable isotopic studies on H_2O in P fluid inclusion of celestite are: μD value is -100.55 (AMOW), $\mu^{18}O$ value is -8.64(SMOW). These values are similar to those of underground hot water. (From authors' abstract by E.R.)

YINQING, Li, WEISHI, Chen and **ZONGYAO, Rui**, 1989, The ore-forming fluid of tin Dachang deposit (abst.): PACROFI Abstracts with Program, Vol. 2 [Second Pan-American Conf. on Research on Fluid Inclusions, Jan. 4-7, 1989, VPISU, Virginia], p. 73. Authors at Inst. Min. Deposits, Chinese Acad. Geol. Sci., Beijing 100037, PRC.

The Dachang belt of ore is a world-famous cassiterite-polymetallic sulfide belt in China. It consists of three fields from NW to SE: the Mangchang field, the Dachang field, and the Beixiang-Fuyongchang field. Each field has similar geological settings, and respectively is taken a biotite granite stock as a center around which varied types deposits occur.

The study of FI in detail shows that the types of FI are many and varied in the ore belt. Varied types deposits in same district have varied associations of FI, but same type of ore deposits in varied district have same characteristics of FI. The transform point T of phase on freezing and heating condition of varied inclusion were measured carefully[sic]. The analysis of gas and liquid phase compositions and hydrogen isotope are carried out; and especially critical state inclusions and CO_2 inclusions have been studied. By making full use of the related phase diagrams of $NaCl-H_2O$ system and $CO_2-NaCl-H_2O$ system the varied information or ore-forming physicochemical conditions of varied deposit in the ore belt are acquired.

Using the melting inclusions of the biotite granite in the area the solidus and liquidus T of the intrusion are presumed, respectively being 700°C±, 1050°C±. Postmagmatic fluid under 700°C gave rise to series of alterations and mineralizations of the intrusion and wall rocks. The ore-forming T of varied deposits are: taken a biotite granite as a center, from near intrusion to far one the T of Sn, Cu, Zn, W(Sb) deposits are 500-200°C, Sb-As-Hg deposits far the intrusion are as lower than 200°C. The lithogenesis P of the main cassiterite-sulphide deposits are about 2×10^7 - 8×10^7 Pa. The emplacement depths of the biotite granite were estimated, ranging from 3-4 Km; the ore-forming depths: the Dachang field is 1-1.5 Km; the Mangchang field is 1.5-3 Km, and 1-3.5 Km for the Beixiang-Fuyongchang field. The ore belt includes a series of hydrothermal deposits which almost of all are related with biotite granite. Through mineralization period it seems there are some evolution trends as following, T change from high to low; salinities gradually decrease, densities have a continuous change from high to low, and to high again; ore-forming solutions have a range of acid $\rightarrow$ neutral $\rightarrow$ weak alkali; high $\rightarrow$ low $\rightarrow$ high for fO_2 of the system. At the mineralization of cassiterite-sulphide the ore-forming solutions mainly appear to be neutral (pH 5); fO_2 are 10^{-24} - 10^{-31} Pa; 0.09-3 for reduce parameters. Ore-forming fluid is rich in F^-, Cl^-, SO_4^{2-} and CO_2. At high T stage the Sn in hydrothermal solution was transported by Sn-bearing fluor-hydroxyl complex $Sn(OH)_4F_2^{2-}$. The hydrothermal fluid related to ore-forming consist of magmatic water and meteoric water among which the ore-forming consist of Sn, Zn, Cu, W and Mo related to mixed hydrothermal solution (mixing of magmatic water and meteoric water), but ore-forming of Sb-As-Hg have closer relations to meteoric water processes. The original fluid of ore-forming principally is one of homogenization phase with high T, and appear to critical and supercritical state at the primal stage. Owing to influences of T, P and component concentrations and so on, the fluid of ore-forming take place immiscible process during ore-forming. At the main mineralization stage of cassiterite-sulphide deposits the vapor phase was separate from the aqueous phase by boiling, from this it came about decomposing of $Sn(OH)_4F_2^{2-}$ and precipitating of SnO_2. Perhaps accumulation of ore pocket of cassiterite has close relation to intense boiling of ore-forming fluid. At Sb-As mineralization stage the partial immiscibility of CO_2 and $NaCl-H_2O$ resulted in ore precipitation. (Authors' abstract)

YONEDA, Tetsuro, 1989, Chemical composition of chlorite with special reference to the iron vs. manganese variation, from some hydrothermal vein deposits, Japan: Mining Geol., v. 39, no. 6, p. 393-401 (in Japanese, English abst.). Author at Dept. Resources Development Engineering, Hokkaido Univ., Sapporo 060, Japan.

Chlorite, which occurs commonly as a gangue mineral in four hydrothermal vein deposits, that is, Chitose, Yatani, Sado and Ohe, was quantitatively analyzed by X-ray microanalyser. Chlorite from Yatani, Sado, and Ohe, is Fe-rich, while chlorite from Chitose is Mg-rich. The chlorite geothermometer (Walshe, 1986) applied to these vein chlorites gives T equivalent to or slightly lower values than those obtained by fluid inclusion thermometry. They contain a large or small amount of manganese (maximum MnO content 1.75 wt % at Sado deposit), and show Fe-Mn compositional variation at more or less constant MgO content in each vein. This is probably owing to their difference of time and space of chlorite formation. For example, the activity of Fe^{2+} ion relative to that of Mn^{2+} ion in hydrothermal solution decreases with T lowering at Chitose and Yatani deposits, while the activity ratio increases with decreasing T at Sado and Ohe deposits.

The exchange of Fe^{2+} and Mn^{2+} between chlorite and hydrothermal solution is a function of physicochemical parameters (e.g., T, oxygen fugacity, pH, total dissolved sulfur, and activity of Mn^{2+} and Fe^{2+} ions in aqueous solution). It is inferred that the compositional variation of chlorite in a vein might be influenced by the local or temporal changes of hydrothermal environments, such as oxidation-reduction state and/or T. (Author's abstract)

YONKEE, W.A., PARRY, W.T., BRUHN, R.L. and CASHMAN, P.H., 1989, Thermal models of thrust faulting: Constraints from fluid-inclusion observations, Willard thrust sheet, Idaho-Utah-Wyoming thrust belt: Geol. Soc. Am. Bull., v. 101, p. 304-313. First author at Dept. Geology and Geophysics, Univ. Utah, Salt Lake City, UT 84112.

The thermal effects associated with emplacement of the Willard thrust sheet within the Idaho-Utah-Wyoming thrust belt have been numerically modeled. FI studies and mineralogy, including illite crystallinity, narrowly limit choice of permissible thermal models. Permissible models have initial thermal gradients between ~30°C/km and fluid P less than lithostatic P.

FI were trapped in syntectonic veins within the basal part of the Willard thrust sheet and in cataclastically deformed basement within the footwall. Th have a bimodal distribution in the Willard sheet with maxima at 180°C and 260°C and a unimodal distribution in the footwall with a maximum at 200°C. These T, along with fluid composition, determine fluid density and define isochores along which the fluids were trapped. Illite crystallinity and mineralogy record maximum T in the range of 300°C to 500°C with somewhat lower maximum T in the footwall.

Thermal models for emplacement of the Willard sheet indicate that the hanging wall undergoes initial rapid cooling, but the footwall undergoes initial warming due to tectonic burial. Later both areas undergo approximately isothermal decompression as erosion proceeds. P-T paths for reasonable parameter values intersect the model isochores and are consistent with mineralogy, as required for a permissible model. The thermal model provides a reasonable framework for understanding the thermal history of the Willard sheet. The models are sensitive to thrust-sheet thickness, initial heat flow, and thermal conductivity. The thermal models are relatively insensitive to erosion history for reasonable erosion rates and to redistribution of heat-producing elements for the low values typical of sedimentary rocks. (Authors' abstract)

YONOVER, R.N., SINTON, J.M., SOMMER, M.A. and GIBSON, E.K., 1989, C-O-H ratios of silicate melt inclusions in basalts from the Galapagos Spreading Center near 95°W: A laser decrepitation mass spectrometry study: Geochim. Cosmochim. Acta, v. 53, p. 3145-3154. First author at Hawaii Institute of Geophysics. Univ. Hawaii at Manoa, Honolulu, HI 96822.

Volatile ratios (primarily of H_2O and CO_2) in individual silicate melt (glass) inclusions in minerals have been analyzed using laser volatilization and mass spectrometry. A Nd-glass laser was used to produce 50-micrometer diameter pits in silicate melt inclusions. Released volatiles were analyzed directly with a computer-controlled quadrupole mass spectrometer. The detection limits for CO_2 and H_2O were on the order of 3×10^{-14} and 3×10^{-13} moles, respectively. The reproducibility for CO_2/H_2O was better than ±9%. The total range of volatile ratios from vitreous silicate glass inclusions contained in a suite of Galapagos lavas were: 0.018 to 1.193 for CO_2/H_2O; 0.002 to 0.758 for CO/H_2O; 0 to 0.454 for CH_4/H_2O; and 0 to 0.432 for Ar/H_2O. The mean CO_2/H_2O from the propagating rift (0.245 ± 0.068) silicate glass inclusions is significantly lower than that of the actively failing rift (0.641 ± 0.241); this difference probably reflects different degrees of degassing during contrasting magmatic histories for the two regions. Relatively undifferentiated failing rift magmas must have relatively short crustal residence times prior to eruption and, therefore, have not undergone significant degassing of CO_2, as would appear to be the case for the more highly fractionated propagating rift magmas. The laser-mass spectrometric system described herein has the ability to act as a point-source probing device that can differentiate between the various volatile sites in minerals and rocks (as well as synthetic materials) on a micrometer scale. (Authors' abstract)

YOO, H-D., WILCOX, W.R., LAL, Ravindra and TROLINGER, J.D., 1988, Modelling the growth of triglycine sulphate crystals in Spacelab 3: J. Crystal Growth, v. 92, p. 101-117. First author at Samsung Advanced Institute of Technology, Kihung-Eup, Kyungki-Do, South Korea.

Two triglycine sulphate crystals were grown from an aqueous solution in Spacelab 3 aboard a Space Shuttle. Using a diffusion coefficient of 2×10^{-5} cm^2/s, a computer simulation gave reasonable agreement between experimental and theoretical crystal sizes and interferometric lines in the solution near the growing crystal. In the absence of convection, crystal growth from solutions will rapidly become slower as the adjacent solution is depleted of solute, unless the growth temperature is lowered to compensate. However, if the temperature is lowered too fast, the growth rate will reach the level at which solvent inclusions are formed (Wilcox, 1983). (From authors' abstract by E.R. and text).

YOUNGMAN, K.J., 1988, Hydrothermal alteration and thermal evolution of the Wairakei-Tauhara geothermal area: Ph.D. dissertation, Univ. Auckland.

The Wairakei-Tauhara geothermal system is situated at the northern end of Lake Taupo, and extends for about 10 km in a northwesterly direction from the base of Mt. Tauhara. It is located near the eastern edge of the Taupo Fault Belt, and one major regional fault, the Kaiapo Fault, and several subordinate faults; Te Mihi, Waiora, Wairakei, and Karapiti pass through the active area of the Wairakei section of the field.

Cores recovered during drilling for geothermal steam in this field form the basis of this study. The petrographic, fluid inclusion, and geochemical analysis of these samples, in conjunction with a re-interpretation of the fluid chemistry and hydrology, have lead to a number of conclusions.

An analysis of the early well discharges indicated that fluid of 255-263°C containing 1595-1550 mg/kg chloride and about 25-29 mMoles of CO_2 per 100 mMoles of total discharge, ascended along the Kaiapo, Wairakei, and Waiora Faults at Wairakei. Fluid, about a kilometre to the east, was both cooler and ~100 mg/kg more dilute. To the west, along the Te Mihi fault, fluid was 10°C hotter and 100 mg/kg more concentrated. This, it is inferred, is the result of mixing between the fault-controlled hot upflow and cool lateral inflows.

The fluid inclusion study here was unusual in that it was almost entirely based upon S inclusions that had formed in primary igneous quartz crystals. These inclusions form as a result of the annealing of fractures within the host quartz and can occur at any T above ~200°C and below the modern boiling point for depth T. Several inclusions indicate that a small additional hydrodynamic component to the fluid P of hydrostatic plus 10% exists, although in one well this appears to have reached 35% at some time. There is, however, no evidence for the large overpressures that are inferred by some for the initiation of hydrothermal eruptions. An alternative hypothesis is put forward that explains these phenomenon as a process of the normal hydrostatic P that occur within this system; namely, that small shallow eruptions can occur under hydrostatic P conditions, but propagate in size and depth to match those found as eruption deposits in most systems.

Fluid inclusions also indicate that the deep upflow has been both hotter in the past and has contained CO_2 contents of up to an order of magnitude greater than that of the pre-exploitation system. This variation in T may indicate variation in deep mixing between the hot upflow and the regional groundwater flux.

Other aspects of the hydrology are illustrated by clay petrography, which has been used here for the first time to indicate the presence of cool lateral inflows into the pre-exploitation system at Wairakei-Tauhara. Cool water enters at the periphery of the system and flows towards the centre of the upflow, warming and ascending as it does so. The presence of these inflows is further evidence of the fault control that exits on the hot upflow.

The hydrothermal alteration mineralogy at Wairakei-Tauhara consists of the assemblage quartz, chlorite, albite, adularia, smectite-illite, wairakite, epidote, sphene, pyrite, and calcite; they are in thermal equilibrium with the present system. The presence of epidote and adularia in two cold wells, both to the east and west of the present thermal activity, is evidence that either the size and/or the location of activity has been different in the past.

Epidote-wairakite co-existence can be explained by CO_2 contents in the fluid of about twice that of the pre-exploitation system, while variation in the Fe content of epidote suggests that CO_2 contents could have been as low as two orders of magnitude less than this at some stages. However, this is consistent with gas loss due to boiling over the T and CO_2 ranges inferred for the field.

Mass transfer within the system can be subdivided into two groups: (a) constituents that are immobile: SiO_2, MnO, MgO, TiO_2, Al_2O_3, total iron, Zr, P_2O_5, V, Y, Nb, Pb, and Ba; and (b) constituents that are mobile: Na_2O, K_2O, CaO, Cs, Rb, Fe^{3+}, Fe^{2+}, NH_3, H_2O^+, CO_2, H_2S, S(O3), Zn, and As. The mass transfers that occur in the second group are the result of five factors: (a) primary phenocryst alteration; (b) recrystallization of the tuffaceous matrix; (c) proximity to permeable channels; (d) boiling and gas separation; and (e) redox reactions.

At Wairakei-Tauhara, the fluid chemistry, hydrology, mineralogy, and mass transfer are all interrelated aspects of the system that are a product of the hydrothermal processes at work there. (Author's abstract)

The CO_2 pressures reported were not measured but deduced by subtracting the melting point depressions due to NaCl based on the known composition of present-day fluids and assuming that the remaining -Tm must be due to the presence of CO_2. Laser Raman probe analysis was attempted at the Bureau of Mineral Resources in Canberra, Australia, but this failed to give reliable gas analyses. (S. Simmons)

YU, Dalong, ZHOU, Dezhong and **YE, Dayuan,** 1989, A preliminary discussion on the genesis of the Mobin quartz vein type gold deposit in Hunan Province: Mineral Deposits, K'uang Ch'uang Ti Chih, v. 8, (1), p. 51-64 (in Chinese).

Indexed under FI. (E.R.)

YUCHENG, L., HALLS, C. and **SPIRO, B.,** 1989, Fluid evolution and isotopic compositions in pegmatites and pneumatolytic lodes from the St. Austell Granite, S.W. England, UK (abst.): ECROFI, European Current Research on Fluid Inclusions, X Symp., London, April '89, Abstracts, p. 98. First author at Dept. Geol., Imperial College, London, UK.

Thermometric and salinity measurements made on FI in quartz and fluorite from pegmatites and veins in the Hensbarrow Cupola are used in conjunction with stable isotope data from quartz and micas to constrain the interpretation of transitional processes leading to the formation of pneumatolytic lodes in the St. Austell granite. An attempt is also made to match the conclusions regarding the physical and chemical evolution of the fluids in the transitional system with some textural and paragenetic evidence.

The initial state of the hydrothermal system is found in FI in miarolytic and stockscheider pegmatites of the inner, Li mica granite. The inclusion population shows that crystallization took place in an evolving fluids system within which Th varies from 250-450°C. The corresponding variations in salinity from 5-45 wt % NaCl eq. reflect a compositional range, the upper part of which is represented by complex multiphase inclusions containing coexisting halite and silicate dms. A significant population of silicate glass inclusions is also present.

Inclusions in quartz from the closely associated greisen-quartz-tourmaline lodes show a Th range comparable to that of the pegmatites (200-450°C). High salinity, multiphase inclusions (30-47 wt % NaCl eq.) are also abundant, and coexisting vapor inclusions suggest that boiling may have been locally important. Two-phase (L + V) inclusions with low to intermediate salinity in the ranges 2-5 and 10-25 wt % NaCl eq. form prominent populations in the Gunheath greisen lodes. This is a feature of quartz from other pneumatolytic facies in Cornwall. This hydrous fluid of intermediate salinity is believed to be the main phase separated from the Li mica granite at the transitional stage. Changes in confining P, due to steps in fracture propagation, caused boiling and further fractionation of this fluid. Independent evidence provided by adiabatic crystallization textures in the lodes and stable isotope analysis is used in support of this interpretation. The problem of fluid mixing in transitional systems is discussed in terms of the interplay between pneumatolytic injection and tectonic extraction. (Authors' abstract)

YUDAWINATA, Koswara, MATSUEDA, Hiroharu and **ISHIKAWA, Yohei,** 1988, Ore texture and mineral assemblages of the Ezuri Kuroko deposits, Akita Prefecture, Japan: J. Min. Coll. Akita Univ., ser. A, v. VII, no. 1, p. 29-73. Authors at Institute of Mining Geology, Mining College, Akita Univ., Japan.

The ore minerals of ore bodies 70 and 35 in the Ezuri mine are divided into three assemblages as follows:

Type 1: Sphalerite-galena-tetrahedrite (-pearceite)
Type 2: Sphalerite-pyrite-chalcopyrite-galena (tetrahedrite)
Type 3: Sphalerite-pyrite-chalcopyrite-galena-tetrahedrite (bornite-digenite)

The Th of fluid inclusions in sphalerite and barite do not show remarkable differences among Type 1, Type 2 and Type 3. The Th of Type 1 ranges from 220°C to 310°C and for Type 2 ranges from 230°C to 340°C. For Type 3, Th ranges from 210°C to 330°C. The salinity of ore-forming fluids obtained from Type 2 (70GO) ranges from 5.1 to 8.2 eq. wt % NaCl.

The environment of ore formation is estimated as follows:

Type 2 (70GO): T = 169°C-208°C
fS_2 = 10^{-12} to $10^{-13.9}$ atm
fO_2 = $10^{-36.8}$ to $10_{-38.1}$ atm
Type 3 (35JO): T = 155°C - 226°C
fS_2 = $10^{-10.8}$ to $10^{-13.5}$ atm
fO_2 = $10^{-36.8}$ to $10^{-38.7}$ atm (From authors' abstract by E.R.)

YUN, C.H., JOHN, Y.W., CHON, H.T. and PARK, S.J., 1989, Genesis of Eunjeok gold-silver deposit: Taehan Kwangsan Hakhoechi 1989, v. 26, no. 1, p. 12-17 (in Korean). Authors at Coll. Eng., Jeonnam Univ., Kwanju, S. Korea.

The Eunjeok (Korea) Au-Ag fissure-filling vein ore deposit is emplaced in rhyolites. The paragenesis of vein minerals is relatively simple, and three distinct depositional stages can be recognized: (1) pyrite-arsenopyrite-sphalerite stage, (2) pyrite-sphalerite-galena stage, and (3) barren quartz and carbonate stage. Electrum, argentite, and native Ag were deposited mainly during stage 2. Th of fluid inclusions of stage 1 and 2 are 215-280° and 220-250°, resp. Salinities of fluid inclusions are 0.8-5.4 wt % eq. NaCl in stage 1, and 2.0-4.3 wt eq. NaCl in stage 2. Ore mineral. suggests that T of the stage 1 could be in the range 310-325°; the T and S fugacities of the stage 2 are 185-230° and $10^{-16.5}$ to $10^{-17.5}$ atm., resp. (CA 112:162313n)

YURIMOTO, Hisayoshi, KUROSAWA, Masanori and SUENO, Shigeho, 1989, Hydrogen analysis in quartz crystals and quartz glasses by secondary ion mass spectrometry: Geochim. Cosmochim. Acta, v. 53, p. 751-755. Authors at Inst. Geosci., The Univ. Tsukuba, Tsukuba, Ibaraki 305, Japan.

Microanalysis of H in quartz crystals and quartz glasses has been developed by secondary ion mass spectrometry (SIMS). The secondary ion intensities of H are proportional to the H contents determined by infrared (IR) absorption over the range of 5 to 3000 ppma H/Si. The correlation between SIMS and IR results indicates that secondary ion yields of H are independent of crystal structure. The SIMS method could reveal correlations between H distribution and hydrolytic weakening at the microscopic level. (Authors' abstract)

ZAGRUZINA, I.A., KAPLUNOV, L.D. and KIRILLOV, A.S., 1989, Chemical composition of fluid phase of microinclusions in minerals of the Urals superdeep drilling SG-4: Doklady Akad. Nauk SSSR, v. 308, no. 3, p. 708-711 (in Russian). First author at All-Union Sci.-Research Geol. Inst., Leningrad, U.S.S.R.

The borehole SG-4 is in the western part of the Tagil megasynclinorium. The depth interval 0-3 km studied by the authors consists of volcanic-clastic rocks of intermediate and basic composition (Imennovskiy complex of the Silurian age). Quartz-carbonate veinlets with sulfides cut these rocks. Isotope studies suggest a homogeneous, high-T deep rock source, typical of basalts. The authors suppose that the volatiles characterize the primary crystallization environment of the silicate components. The paper presents results of mass spectrometric studies of the volatiles at ca. 2400 m. The mineral sample (~0.1 mg) was placed in a heated container directly at the source space of the mass spectrometer MI 1305, and T increased from room T to 800°C at 10°C/min. H_2O and CO_2 are the main components in all samples (pyroxene, plagioclase, amphibole + pyroxene and calcite). Hydrocarbons (CH_4, C_2H_6), N_2 and CO are present in inclusions in small amounts; moreover, at 100 to 400°C the emission of C_3H_3 from pyroxene and plagioclase and at T > 500°C potassium was released from minerals. H_2S and products of its dissociation (HS^-, S) were also noted. Minerals taken from deeper levels yield more H_2O at higher T than those taken from shallower levels. Similar differences were found for CO_2, CH_4 and C_2H_6. All volatiles are released from inclusions simultaneously. (A.K.)

ZEEH, S., MAUL, B., ECHSTÄDT, McKENZIE, J.A., KINDLE, P.J., RIEKEN, R. and RICHTER, D.K., 1989, Cement-stratigraphy of upper Wetterstein limestone (Triassic, Australia): Clue to timing of lead-zinc mineralization (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-427-428. First author at Geologisches Institut der Universität Freiburg, Freiburg, West Germany.

With progressive burial and T increase, O isotopes become strongly negative, relative to the PDB standard (blocky calcite I $\delta^{18}O$ -6.92; blocky calcite II $\delta^{18}O$ -5.50; saddle dolomite I $\delta^{18}O$ -5.50; saddle dolomite II $\delta^{18}O$ -9.55). First results of fluid inclusion studies of late diagenetic stages reveal Th between 90°C and up to 250°C (saddle dolomite II and blocky calcite II). Especially the Th of the saddle dolomites II are distinctly higher than those reported for saddle dolomites by Radke and Mathis (1980).

The Triassic Pb-Zn mineralization of the Eastern Alps cannot be considered "syngenetic"; they are normal epigenetic Mississippi-Valley type Pb-Zn deposits. (From authors' abstract by E.R.)

ZENG, Yishan, AI, Ruiying and WANG, Fengzhen, 1989a, Solubility of the magnetite + hematite buffer assemblage in NaCl solution at 300°C and 500 bar: Chinese Sci. Bull. (Kexue Tonghau), v. 34, no. 24, p. 2050-2054 (in English).

See next item. (E.R.)

ZENG, Yishan, AI, Ruiying and WANG, Fengzhen, 1989b, Solubility of the magnetite + hematite buffer assemblage and iron speciation in sodium chloride solutions at 300°C and 500 bars: Geochim. Cosmochim. Acta, v. 53, p. 1875-1882. Authors at Dept. Geology, Peking Univ., Beijing 100871, P.R.C.

The solubility of the buffer assemblage magnetite + hematite in 0.10, 1.00 and 3.00 mol/kg NaCl solutions with various pH values was determined by use of a Dickson gold cell hydrothermal apparatus at 300°C and 500 bars. Activities of H^+ and Cl^- in the NaCl hydrothermal solution for each determination were approximated.The experimental results show that the solubility is strongly dependent on the pH of the solutions and appears to have no explicit relation to NaCl molality in acidic solutions. The correlation of the measured solubility with pH at 300°C suggests a change in Fe speciation in solution at pH ≈ 5.3-5.4. The present study demonstrates that the change in acidity of hydrothermal ore-forming solutions exerts an important influence on the transport and deposition of Fe in nature. (From authors' abstract by E.R.)

ZHANG, Jiuling, 1989, On the ore-controlling condition and metallogenic prognosis of the Taolin Pb-Zn deposit, Hunan: Geology and Prospecting, v. 25, no. 4, p. 1-7 (in Chinese, English abstract).

The Taolin Pb-Zn deposit is situated in the northern limb of the regional syncline and occurs in the upper Sinian Doushantuo and Dengying Formations. It is a fluorite Pb-Zn deposit of sedimentary-hydrothermal reformed type and distinctly governed by stratigraphy and tectonics. On the basis of such an understanding, three prospect areas were delineated by metallogenic prognosis, and one of the areas (Aobeiwu) was tested by nine drill holes which encountered commercial ore bodies at depth. (Author's abstract)

A table (p. 4) shows analyses of two samples for H_2O, CO_2, CH_4, H_2, CO, Ca, Mg, K, Na, F, and Cl. (E.R.)

ZHANG, Lan, 1989, Hydrothermal alteration and fluid-rock interaction in drillholes WK215 and WK207, Wairakei geothermal field, New Zealand: M.S. thesis, Univ. Auckland.

The petrology of cores from drillholes WK215 (824 m) and the deeper part of well WK207 (1003 m) in the western area of the Wairakei geothermal field have been studied. The stratigraphy in these wells is Wairakei Lapilli Tuff (>88 m), Huka Falls Formation (189 m), Waiora Formation (347 m) and Wairakei Ignimbrite (>94 m). Thicker Waiora Valley Andesite (49 m) occurs at the bottom of the Waiora Formation, and minor dacite was found at 914 m of WK207. The hydrological characters of rocks taken from these two wells show that the primary permeability in the Waiora Formation of WK215 is higher than that of WK207 due to the presence of hydraulically fractured breccias. The permeability of the Huka Falls Formation in WK215 is apparently higher than other wells in the eastern part of Wairakei due to the occurrence of the conglomerates. Hydrothermal alteration minerals present in these two wells include quartz, adularia, albite, epidote, clinozoisite, smectite, illite/smectite, illite, chlorite and calcite as well as wairakite, scolecite(?), mordenite, clinoptilolite and titanite. The T, permeability and fluid state are consistent with the alteration minerals and correspond to downhole measurements. The minerals are zoned: the smectite-i/s-calcite zone corresponds to a sharp T gradient at shallow depth in WK215, in which a steam zone developed. The mineral assemblage, illite-chlorite-wairakite, occurs throughout the Waiora Formation in both wells, and good T (>250°C) and permeability are indicated by the occurrence of abundant epidote, adularia and quartz (442-587 m) in WK215. A subzone of euhedral albite + smectite (472-503 m) is present within the main permeable zone (T = 246°C) and may indicate a local decrease of permeability here.

There is only slight alteration in cores from the bottom of WK215, and a T inversion here suggests that there is lateral fluid flow. The downhole T measurements also show the existence of T inversion in WK207. These indicate that the fluid source is not beneath these two wells but may be further west of WK207. The vein minerals such as calcite, quartz and wairakite are more abundant in WK215 than that in WK207; they correspond to widespread boiling in WK215. The mineral-fluid equilibria in these wells have been calculated by the program "WATCH 1" and also indicated by Activity diagrams, which show that mineral stabilities are controlled by T, boiling, pH and Eh. Quartz, epidote, wairakite, adularia, calcite and illite are in chemical equilibria with thermal fluid from these two wells. Mass transfer within cores from these two wells have also been calculated and show net addition of MgO, H_2O and As at shallow depth. K_2O, SiO_2, Rb and Ba increase significantly in rocks within the main permeable zone, whereas Sr has been lost.

Fluid inclusion study records the evolution of this part of the Wairakei system. A slightly higher (~4°C) T in the main aquifer (442-587 m) and a significant cooling (~28°C) in the deeper part of WK215 are suggested by the measurements. At least three thermal fluids have been supplied to the system. The earliest fluids had high Th (270-290°C) and relatively high salinity (Tm = -0.6°C). The second fluid was cooler (245-265°C), but of lower salinity (Tm = -0.4 to -0.0°C). This was probably caused by dilution of the thermal fluid with deeper circulating meteoric water. The later fluid is represented by the inclusions trapped in a twinned quartz crystal* in which some S inclusions occur along microfractures near its boundary. The third type of fluid was cooler (~245°C) but slightly more saline (Tm = -0.5 to -0.7°C) and was probably concentrated by boiling. (Author's abstract)

*Note that 528 fluid inclusions were studied in this specimen; most, however, are S or PS in origin. Approximately 80 more fluid inclusions were studied in four other quartz and calcite crystals. Tm ice in all but one quartz crystal range from -0.6 to 0.0. The exception contains fluid inclusions with Tm ranging from -0.3 to +1.1°C which suggests that some inclusions may have formed gas (CO_2) hydrates upon freezing. (S.F. Simmons)

ZHANG, Liang, LIU, Jingxiu, ZHOU, Bo and CHEN, Zhensheng, 1989, Oxygen isotope equilibration systematics between quartz and water: Salinities effect problem (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-434.

ZHANG, Ligang, 1989, Stable isotopic compositions of three major types of W-Sn ore deposits in southern China (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-434-435. Author at Yichang Inst. Geology and Mineral Resources, CAGS, Hubei, P.R.C.

The published and unpublished data have been used in this paper to study synthetically the related problems of tungsten ore deposit geneses in southern China. The data include more than 800 O isotope analyses of minerals and rocks, and large number of H, sulfur, carbon, Pb, and strontium isotope data of minerals and fluid inclusions in the 34 W/Sn ore deposits. Based on the greatest amount of the stable isotope data, I propose that the W/Sn ore deposits in China may be subdivided into three extreme types: reequilibrium magmatic hydrothermal W/Sn veins, meteoric hydrothermal W/Sn ore deposits, and stratiform w/Sn ore deposits. (From authors' abstract by E.R.)

ZHANG, Ligang, LIU, Jingxiu, ZHOU, Huanbo and CHEN, Zhensheng, 1989, Oxygen isotope fractionation in the quartz-water-salt system: Econ. Geol., v. 84, p. 1643-1650. Authors at Yichang Inst. Geology and Mineral Resources, Chinese Academy of Geological Sciences, P.O. Box 502, Yichang, Hubei 443003, P.R.C.

Oxygen isotope fractionation accompanying the hydrothermal crystallization of quartz from silica gel has been studied at T between 180° and 550°C under salinities of 0, 5, 25, and 40 wt % to assess the effect of the salinity, the Δ_i value, the reaction mechanism and the T on the isotope fractionation. The findings suggest that oxygen isotope equilibrium between silica gel and pure water at low T cannot be established. Factors affecting the exchange rate between oxygen-bearing phases include salinity of solution, Δ_i value, and T. The authors of this paper do not agree with the conclusion on salt isotope effect reached by Truesdell (1974).

The T dependence of oxygen isotope fractionation between quartz and water from 180° to 550°C and salinities of 5.25, and 40 wt % is $1000\ ln\ \alpha(Q{\cdot}H_2O) = 3.306 \times 10^6\ T^{-2} - 2.71$. (Authors' abstract)

ZHANG, X., NESBITT, B.E. and **MUEHLENBACHS, K.**, 1989, Gold mineralization in the Okanagan Valley, southern British Columbia: Fluid inclusion and stable isotope studies: Econ. Geol., v. 84, p. 410-424. First author at Dept. Earth and Atmospheric Sciences, Purdue Univ., West Lafayette, IN 47907.

Two styles of precious metal vein mineralization, epithermal and mesothermal, occur in the Okanagan Valley of southern British Columbia. the epithermal deposit (Dusty Mac) is composed of quartz stockwork mineralization in Eocene volcanic and volcaniclastic rocks. The mesothermal deposits (Fairview and Oro Fino) consist of thick (1-10 m) quartz veins in Paleozoic and Mesozoic metamorphic rocks. FI and stable isotope studies indicate that two distinct hydrothermal fluids were responsible for the mineralization events. At Dusty Mac, the epithermal fluid had a relatively low T (230°-250°C), extremely low salinity (<1 eq. wt % NaCl), and low $\delta^{18}O$ (-7 to -9‰), and δD (-133‰) values. At Fairview and Oro Fino, the mesothermal fluids had higher T (280°-330°C), significant CO_2 contents, and higher salinities (3-6 eq. wt % NaCl). Stable isotope data show that the mesothermal fluids had low δD (-121 to -148‰) and $\delta^{13}C$ (-8.5‰) values, but high $\delta^{18}O$ (+4 to +6‰) values. The data indicate that the fluids involved in both styles of mineralization are ^{18}O-shifted meteoric water, with shallow circulation responsible for the epithermal deposits and deep circulation involves in the formation of the mesothermal deposits. Although both styles of mineralization occur in the same tectonic regime, it appears that they are not temporally or genetically related to each other. (Authors' abstract)

ZHANG, Y-G. and **FRANTZ, J.D.**, 1989, Experimental determination of the compositional limits of immiscibility in the system $CaCl_2$-H_2O-CO_2 at high temperatures and pressures using synthetic fluid inclusions: Chem. Geol., v. 74, p. 289-308. Authors at Geophysical Laboratory, Carnegie Institution of Washington, Washington, D.C. 20008.

Abstract in Fluid Inclusion Research, v. 21, p. 451-452. (E.R.)

ZHANG, Y-G. and **FRANTZ, J.D.**, 1989, Investigations of fluid properties in the CO_2-CH_4-H_2O system using synthetic fluid inclusions: Ann. Rept. Dir. Geophys. Lab., Carnegie Inst. Wash. 1988-1989, p. 65-72.

ZHANG, Y.G., HICKMOTT, D., FRANTZ, J.D. and **HOERING, T.C.**, 1989, Use of zeolites and silica gel for loading gases in hydrothermal experiments (abst.): 28th Int'l Geol. Cong. Abstracts, p. 3-441-442. Authors at Carnegie Inst. Washington, Washington, DC.

An interesting property of the synthetic zeolite, molecular sieve 5A, is that at low T it can sorb large quantities of non-condensible gases such as N_2, Ar, CH_4, and O_2. These adsorbed gases are released with rising T, and, under hydrothermal T and P, the zeolites break down to a feldspar and H_2O. Silica gel exhibits similar properties and recrystallizes to quartz under hydrothermal conditions.

Because of the large adsorption capacity of gases by zeolites and silica gel, they can be used to load common gases or gas mixtures in noble-metal capsules used in hydrothermal experiments. Possible experimental uses of this gas loading technique include: (1) studies of metamorphic phase equilibria over the full range of naturally-occurring fluid composition, (2) diffusion studies of gases into minerals, and (3) studies of supercritical mixed-volatile fluids using synthetic fluid inclusion techniques.

To test the technique, a piece of fractured quartz and small amounts of zeolite and silica gel or just silica gel (~100 mg) were added to a Au capsule. The capsule was connected to a gas pipette containing a known volume of gas. The gas or gas mixture was then condensed into the gold capsule by cooling with LN_2. After the volatiles were drawn into the capsule, the capsule was crimped, cold-welded, and then electrically welded. The capsule was heated under confining P in a cold-seal hydrothermal P vessel (500°C, 2000 bars). After quenching experiments containing zeolite, the phase was found to have reacted with the silica gel to form feldspar, thus releasing water. Synthetic fluid inclusions containing the gas mixtures were found to have formed in the fractured quartz prism. Gas compositions in the capsule were measured using gas chromatography.

The experimental studies of synthetic fluid inclusions, the phase equilibria of gas mixtures, and the equilibria between gas mixtures and mineral assemblages have long been hampered by difficulties in loading known amounts of volatiles in hydrothermal charges. The technique presented above should greatly facilitate further advances in these areas. (Authors' abstract)

ZHANG, Youxue and **ZINDLER, Alan,** 1989, Noble gas constraints on the evolution of the earth's atmosphere: J. Geophys. Res., v. 94, no. B10, p. 13,719-13,737. Authors at Lamont-Doherty Geological Observatory and Dept. Geological Sciences, Columbia Univ., Palisades, NY.

A model for the degassing of Xe, Ar, and He from the Earth has been constructed. The Earth is divided into three idealized reservoirs in terms of their noble gas inventories: undegassed mantle, degassed mantle or mid-ocean ridge basalt (MORB) mantle, and atmosphere plus continental crust. Degassing is assumed to occur via the partitioning of gases between a vapor phase and basaltic melt, in accord with He-Ar isotope systematics which require that ^{3}He be degassed at a slower rate than ^{36}Ar on average. The model successfully reconciles presently available isotope ratios of ^{129}Xe/^{130}Xe, ^{40}Ar/^{36}Ar, and ^{4}He/^{3}He in the different Earth reservoirs, and accurately predicts the present degassing rates of He and Ar. This is the first time that noble gas isotope data have been shown to be consistent with a single degassing model. Because the degassing is likely to be solubility controlled at some level, study of noble gases alone does not fully constrain the evolution of the atmosphere. However, the model can be extended to major gaseous species in the Earth's primary atmosphere if the relevant solubilities are known. Similarities between the solubilities of CO_2, CO, and He, and between N_2 and Ar, suggest a mean age for the total atmosphere on the order of 4.4 to 4.3 Ga. The formation of the oceans was a much later event because of the much higher solubility of H_2O in silicate melt. If H_2O has been the primary outgassing species for ocean water, the oceans have a mean age on the order of 2.7 Ga, suggesting that the volume ratio of continental crust to the oceans might have remained relatively constant during Earth history. (From authors' abstract by E.R.)

ZHANG, Youxue, STOLPER, E.M. and **WASSERBURG, G.J.,** 1989, The mechanism of water diffusion in silicate melts (abst.): Eos, v. 70, p. 501. Authors at Div. Geol. and Planet. Sci., 170-25, California Inst. Tech., Pasadena, CA 91125.

The mechanism by which "water" diffuses in silicate melts and glasses may be as H_2O molecules, OH groups, proton jumping, etc., and is at present controversial. We infer that molecular H_2O is the dominant diffusing species during water diffusion in silicate melts. (From authors' abstract by E.R.)

ZHOROV, Yu.M., BELETSKIY, I.V., PAUSHKIN, Ya.M. and **SHEBEL'KOVA, L.V.,** 1989, Pyrolysis of the petroleum fractions in the presence of metal melts: Doklady Akad. Nauk SSSR, v. 305, no. 5, p. 1167-1169 (in Russian). Authors at Moscow Inst. Petroleum and Gas, Moscow, USSR.

The paper describes pyrolysis of gasoline, kerosene, pyrocondensate C_5 and fuel oil at 850°C in the presence of a Pb + Bi molten alloy, contact time 0.2-1.2 sec, to yield C_2-C_4 olefins, it also mentions pyrolysis in contact with alkali chlorides and hydroxides; pertinent to the hydrocarbon species present in magmatic inclusions. (A.K.)

ZHU, Meixiang, 1989, Hydrothermal alteration in the Yangying geothermal field of Tibet, China: *in* D.L. Miles (ed.), Water-Rock Interaction WRI-6, Rotterdam, Balkema, p. 813-816. Author at Geothermal Research Section, Geology Dept., Peking Univ., Beijing, P.R.C.

The volcanic rock and granite-porphyry near faults in the field have been altered by geothermal fluid upwelling along the fault. The alteration-rank and zonal pattern of hydrothermal assemblages are controlled by T of fluid and depth. According to the pattern, the prospecting place may be between F1 and F2 in the north, although the highest T (201°C) measured so far occurs in the south. (Author's abstract)

Temperatures given refer to fluid inclusion Th values. (E.R.)

ZHU, Meixiang and **XU, Yong,** 1989, Hydrothermal alteration in the Yangbajain geothermal field, Tibet: Scientia Geologica Sinica, Ti Chih K'o Hsueh/Dizhi Kexue, v. 2, p. 162-174 (in Chinese).

ZOTOV, A.V., BARANOVA, N.N., DAR'YINA, T.G. and **BANNYKT, L.N.,** 1989, Gold(I) complexing in the KCl-HCl-H_2O system at 450°C and 500 atm: Geokhimiya, no. 4, p. 541-550 (in Russian).

Translations

Items presented here are selected on the basis of (1) availability of a translation that has not been published elsewhere; (2) significance to inclusion research; and (3) date of publication. Thus, particularly significant older items are sometimes included. Further iterations between translator (or author) and editor would make for a more polished translation, but more rapid publication was considered more important than polish. The editors would welcome suggestions from readers as to other papers that should be translated and would particularly appreciate copies of privately-made translations not heretofore published.

DELITSYNA, L.V., DELITSYN, L.M., PAVLOV, E.G., KOLESNIKOV, V.M. and TOV, G.M., 1989, Immiscibility of liquid phases in the system $Ca_5(PO_4)_3F$-SiO_2-NaF-CaO-MgO and its significance in the genesis of apatite ores: Doklady Akad. Nauk SSSR, v. 305, no. 1, p. 162-166 (in Russian). Authors at State Sci.-Research Inst. Mineral and Chemical Raw Materials, Lubertsy, Moscow Region, USSR.

Studies of the liquation genesis of the apatite-nepheline ores at Khibiny have been made in the system consisting of 13 essential components: P_2O_5-SiO_2-TiO_2-Al_2O_3-TR_2O_3-Fe_2O_3-FeO-CaO-MgO-SrO-Na_2O-K_2O-F. Every component is involved in the reaction to form the immiscible liquid phases. For an explanation of the influence of CaO and MgO on melt liquation in this complicated system, studies have been made of the following joins: $Ca_5(PO_4)_3F$(apatite, Ap)-SiO_2-NaF and $Ca_5(PO_4)_3F$-SiO_2-NaF-CaO-MgO.

Experimental studies have been performed using the quenching method on synthetic compositions. It has been found that in the system Ap-SiO_2-NaF there is a broad field of two immiscible liquid phases: silicate and phosphate-fluoride. Silicate melts easily form glasses on quenching, but phosphate-fluoride melts always crystallize. Morphology of the immiscible liquid phase (droplets, layers, etc.) is preserved in the quench products. Mutual solubility of the liquid phases is limited, and up to 1400°C it does not exceed 5-7%. With T increase from 1000 to 1400°C the liquation field of the melts extends due to melting of higher -T components toward the side join Ap-SiO_2 (Fig. 1) The refractive index of the silicate glass from the immiscibility field depends to a high degree on the Ap content in the starting material and on T of melting (Table 1). A narrow field of homogeneous melt occurs along the join Ap-NaF, and up to 1400°C no significant increase of the SiO_2 solubility in the salt melt has been observed. When the starting material bearing <5% SiO_2 has been melted, homogeneous melts have been formed; when SiO_2 content equalled 10%, the melts have been two-phase, and after quenching numerous tiny (0.0n-0.n mm dia) droplets of silicate glass are found in the phosphate-fluoride layer. No homogeneous melt has been found in the SiO_2-rich corner up to 1400°C; silicate melts in this part of the system display strong opalescence.

On the basis of the data in [1] and according to our work, in the section SiO_2-NaF there is a field of two immiscible liquid phases. Liquidus in the system SiO_2-NaF has an S-shaped habit, indicating a non-binary nature [sic]. According to [2], this can be explained by the reaction between SiO_2 and NaF:

$$6SiO_2 + NaF = Si_4O_7F_2 + Na_2Si_2O_5 ,$$

Table 1. Immiscibility field of melts in the system Ap-SiO_2-NaF.

T, °C	Surface of the immiscibility field, %	Starting material, wt %			Refractive index of the silicate glass for various apatite contents, %
		Ap	SiO_2	NaF	
1000	18	0-42	5-30	95-40	$\frac{1.490}{\text{Ap} < 10}$ $\frac{1.515}{\text{Ap 10-40}}$
1000	37	0-55	5-55	95-30	$\frac{1.490}{\text{Ap} < 10}$ $\frac{1.515}{\text{Ap 10-30}}$ $\frac{1.540}{\text{Ap 30-55}}$
1200	51	0-65	7-65	93-20	$\frac{1.490}{\text{Ap} < 10}$ $\frac{1.515}{\text{Ap 10-20}}$ $\frac{1.575}{\text{Ap} > 20}$ $\frac{1.472}{SiO_2 > 50}$
1400	62	0-75	7-75	93-15	
1700	86 (assumed)	2-90	98-10	-	

that indicates a depolymerizing role for fluorine with respect to the SiO_2 tetrahedra. On the other hand, according to data from [3], in the system Ap-NaF, between apatite and NaF there occurs the following reaction:

$$Ca_5(PO_4)_3F + 6NaF = 3Na_2CaPO_4F + 2CaF_2 ,$$

a partial section of the system Ca,Na || PO_4,F (Fig. 2). Thus, the system studied by us is a part of the system Ca,Na || PO_4,SiO_4,F, and compositions of the equilibrium melts do not occur in the plane of the diagram.

Studies of the opalescent glasses by electron microscope showed that in the silicate glass matrix there occur droplets of spherules of salt melt [...] of dia. in the ranges 1000-10,000 Å. Spherules join by forming necks between them. They evidently are an emulsion in a more viscous silicate melt. The maximum amount of salt droplets dispersed in the silicate matrix is 35-40%. In the salt phase, which does not quench to a glass, X-ray diffraction revealed $Ca_5(PO_4)_3F$ (apatite), NaF, CaF_2, Na_2CaPO_4F (nacaphite), $Ca_4Si_2O_7F_2$ (cuspidine), Na_2SiF_6 (malladrite), $CaSiF_6$. These data seem to indicate the occurrence in the system Ca,Na || PO_4,SiO_4,F of intermediate reactions, causing a decrease in the T of melting of all the substances melting normally at high T, and the formation of immiscible liquid phases.

Additional introduction of CaO in the system Ap-SiO_2-NaF (in addition to the Ca present in apatite) and MgO causes a significant decrease in the immiscibility field reflected in an increase of the mutual solubility of the immiscible melts. Figure 3 shows the influence of CaO and MgO additions (above 100%) on the liquation field in the system Ap-SiO_2-NaF for the 1100°C isotherm. Without CaO the immiscibility field occupies 37% of the diagram, with 5.3% CaO - 30%, 11% CaO - 21%, 17.7% CaO - 15%, and 25% CaO - only 8%. With 17.7% CaO the immiscibility field already does not touch the join SiO_2-NaF. MgO causes an even stronger increase in the mutual solubility of the immiscible melts than CaO: with 2% MgO (above 100% of the basic composition), the immiscibility field makes up 26% of the diagram (Fig. 3), with 5.3% MgO - 22%. With 5.3% CaO or 2% MgO in the starting material, the solubility of SiO_2 in salt melt increases to ~15%. During the decrease of the immiscibility field, the area of the homogeneous melt extends, but the total area of liquid phase differs insignificantly from the system Ap-SiO_2-NaF at 1100°C. The most distinct separation of melts to form two layers, silicate and salt, at 1000-1200°C, occurs when Ap content in the starting material equals at least 10-15%. Higher Ap content causes an emulsion to form, strongly complicating the measurements of the refractive indices of the glass. In such case, the silicate glass bears a lot of salt droplets (Fig. 4), and the phosphate-fluoride layer contains numerous spherules of transparent silicate glass. Refractive index of the glass distinctly increases depending on the Ap content in the starting material. In the T interval 1100-1200°C with 10% Ap, n of the glass varies from 1.473 to 1.479; with 10-30% Ap—from 1.509 to 1.519; with Ap > 30%—from 1.525 to 1.551.

The experimental data obtained permit the supposition that the excess (above the apatite composition) of CaO and MgO dissolved in alkaline magma is a factor inhibiting the liquation of apatite-rich melts. It is fully understandable that with an excess of CaO and MgO in magma, in the process of its liquation the silicate melt will dissolve a higher amount of phosphates and the separating phosphate melt—a higher amount of the silicate components. Hence, ore bodies forming due to liquation should be poor in apatite and relatively rich in nepheline, pyroxenes and other silicates. In the apatite-nepheline ores and connected ijolite-urtites of the Khibiny massif the essential amount of CaO occurs in apatite (5-80%) and in pyroxene (30-75%), and Mg—in pyroxene. The excess (above apatite) amount of CaO and CaO + MgO in apatite-nepheline ores is 1-3 absolute % and 1.5-3.5 absolute % (5-25% relative to apatite), whereas in ijolite-urtites it is 3-8 absolute % for CaO and 4-12 absolute % for MgO + CaO (250-2000 relative %). A

Table 2. CaO, MgO and P_2O_5 contents in massive ijolite-urtites.

		Components, wt %			Excess above the apatite composition, %	
Part of the ijolite-urtite belt	No. of samples	P_2O_5	CaO	MgO	CaO	CaO + MgO
SW ore field	6	$\frac{0.79}{0.53}$ *	$\frac{4.00}{1.60}$	$\frac{1.16}{0.71}$	2.99	4.15
E section	17	$\frac{0.90}{0.52}$	$\frac{5.03}{1.78}$	$\frac{1.63}{0.56}$	3.88	5.51
NW margin	7	$\frac{1.31}{1.17}$	$\frac{5.70}{2.74}$	$\frac{1.81}{1.41}$	4.02	5.83

* Above the dash—arithmetic mean; under the dash—standard deviation.

tendency in the distribution of CaO, MgO and P_2O_5 in massive urtites at various places of the ijolite-urtite belt is remarkable here. Calculation of the average contents of these components in massive ijolite-urtites connected with apatite-nepheline ore bodies, performed on the basis of the data published in [4-6], has shown that the NW margin is enriched in CaO and MgO when compared with SW and E parts of the belt (Table 2). It is characteristic that in this NW margin there occurs the poorest apatite deposit, the apatite-nepheline ores named Partomchorr-Lyavoyok. (Translated by A. Kozlowski, Warsaw, 29/VII/1989.)

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(Received 18/XI/1987)

Figure 1. Melt immiscibility fields in the system Ap-SiO_2-NaF: 1—one melt (1L), 2—two melts (2L), 3—incomplete melting, 4—edge of the two-melt field at 1400°C.

Figure 2. Diagram of the join system Ca,Na ‖ PO_4,F.

Figure 3. Melt immiscibility field in the system Ap-SiO_2-NaF-CaO,MgO (1100°C isotherm). Numbers 1-3 are the same as in Figure 1.

Figure 4. Melt immiscibility in the system Ap-SiO_2-NaF-CaO (Ap 20, SiO_2 50, NaF 30, in wt %, plus CaO 5.3), 1200°C, 1 hour. Spherules are phosphate-fluoride melt, matrix is silicate melt.

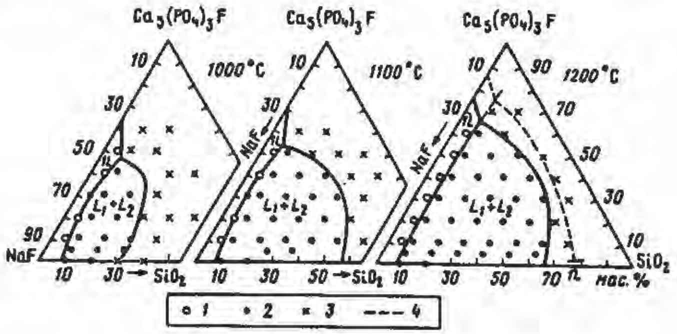


Figure 1

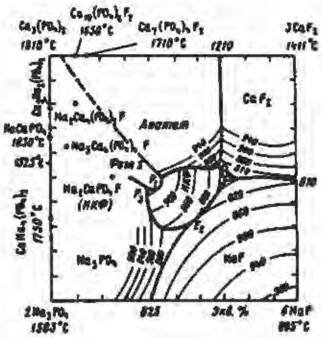


Figure 2

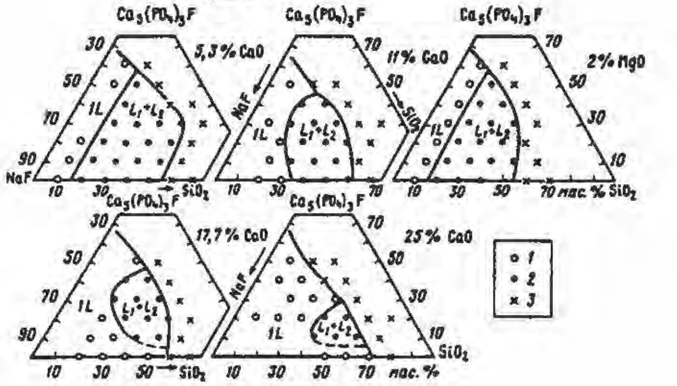


Figure 3

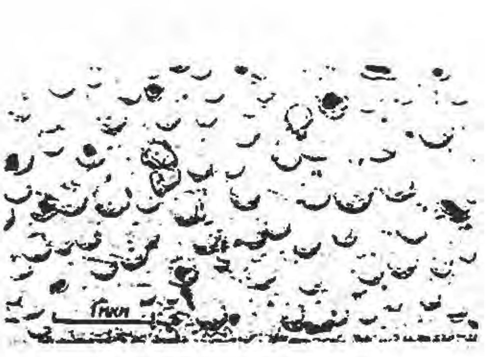


Figure 4

GRISHINA, S.N., 1988, Inclusions in halite from a contact metamorphism zone of the Siberian platform, *in* N.V. Sobolev, ed., Thermobarogeochemical Studies of Processes of Mineral Formation: Novosibirsk, Nauka Publ. House; pub. of Inst. Geol. and Geophysics no. 733, ISBN 5-02-028807-1, p. 200-206 (in Russian, translation courtesy Dr. S.N. Grishina).

Mineral-geochemical transformations in magma-salt aureoles are described in detail (1,2,3) while FI in salts are only mentioned, with no systematic investigations being carried out. This paper deals with specimens of Cambrian rock salt of the Siberian Platform taken from 20 wells which cross dolerite series [sills?]. The specimens were taken at different distances from the trap inclusions, in zones of their active effect and somewhat apart. The specimens on the contact with dolerite bodies are usually represented by macro- and megacrystalline salt; the medium-grained specimens occur as an exception (Chitorminskaya and Changuilskaya areas).

No relicts of "chevron" or diagenetic halite were found in zones close to the trap body. Aqueous inclusions are rare or absent. Inclusions of condensed gases trapped with a variable water phase or practically water-free are the most widespread type. The inclusion distribution is highly heterogeneous and irregular. Total contents of inclusions are notably low. Some large crystals are completely free of FI. Only the specimens of the Kochumdekskaya and Chitorminskaya areas taken near intrusive bodies 7 and 0 m apart, respectively, have shown a higher content of CO_2 inclusions, up to 100-150 per cm^2, while their contents in other specimens seldom exceed 20-25 per cm^2. Water-free inclusions of condensed gases as well as aqueous and H_2O-CO_2 inclusions occur alone or in different combinations with the above types independently at a distance from the trap intrusion.

Solid inclusions of metamorphosed halite are characteristically variegated as compared with sedimentary-diagenetic halite. The most typical minerals are anhydrite, dolomite, chalcopyrite, pyrite, pyrrhotite, magnetite, sulfur, and amphibole. The anhydrite inclusions are markedly different from those in diagenetic specimens. In metamorphosed halite, they are mainly tabular in shape and occasionally occur as irregular grains. The crystals are usually fractured or corroded. Acicular crystals in radiaxial aggregates grown on terrigenous material or random individual crystals are typical of contact metamorphic halite.

A part of the solid inclusions in metamorphosed specimens seems to be due to crystallization of the substance rather than to trapping of extraneous particles. These are, first of all, waterless salt inclusions, predominantly of chlorine-calcium composition and oriented enclosed crystals of sylvite in halite. Solid salt inclusions occur in halite grains together with essentially CO_2 inclusions. The shapes of solid salt and CO_2 inclusions are in accordance with each other; rounded and spherical CO_2 inclusions are found along with solid salt inclusions of rounded shape. When the CO_2 inclusions are octahedra, the solid salt inclusions assume a clearly negative shape.

A majority of metamorphosed halite specimens contains sylvite inclusions in the form of irregularly arranged isometric, rounded or elongated inclusions. Some specimens contain sylvite whiskers with cube and rhombic-dodecahedron orientation. The presence of sylvite [inclusions] that were not found in salts of the less metamorphosed parts seems to be due to crystallization of KCl impurity out of the melt, which earlier was dispersed in a solid phase (Petrichenko et al., 1976). The octahedral sylvite inclusions have been found in a salt xenolith in dolerite. The rounded inclusions of sylvite are observed in the form of solidified drops adhered to solid inclusions of anhydrite, which seems to be evidence of trapping sylvite in the liquid form.

Large crystals were determined by V.V. Dolishny (IGiGGI, Ukrainian Acad. Sci.) using X-ray methods. Small separate crystals of the whisker type as well as thin scaly crystals were determined by nondestructive Raman spectrometry on a multichannel microspectrometer of the OMARS-89 type. The reference pyrrhotite Raman spectra and pyrrhotite inclusions from specimens are shown in Figure 4 [sic].

Among 20 halite specimens taken in the affected aureole of the trap intrusions, eight specimens contain inclusion of condensed gases without traces of aqueous phase. In other specimens, besides the essentially gas inclusions, brine and brine-CO_2 inclusions have been found.

Essentially CO_2 inclusions in halite are single-phase liquid at room T. The morphology of essentially CO_2 inclusions is different, the typical form of inclusions being preserved for every specimen. The most frequent shape is that of negative halite crystal with rounded tops. Small inclusions of this morphology are associated with every one of the following shapes: (1) cubic (Srednenepskaya, Fig. 1a,b); (2) spherical (Nizhnetungusskaya-4, Fig. 1c); (3) octahedral (Kochumdekskaya-3, Chitorminskaya-165, Fig. 1d); (4) oval (Verknekhatangskaya, Fig. 1e), sometimes with inclusion migration traces (Tubinskaya, Fig. 1f); (5) a cube modified by octahedron and hexoctahedron faces (Nepskaya, Fig. 1g).

The comparison of inclusion shape with other characteristics under study permits a correlation between the octahedral shape and a water-free composition. The specimens containing the octahedral inclusions are close to the intrusive bodies. The specimens which are far from an intrusive usually contain cubic inclusions.

The data of freezing investigations (Fig. 2) have shown that condensed gas inclusions consist, predominantly, of CO_2. This is supported by the range of CO_2 melting points -56.6 to -57°C, which is close to the melting point of pure CO_2 (-56.6°C). Only two specimens—Danilovskaya 22 (1361 m) and Kholokitskaya 1 (2546 m)—have shown an essential difference of the CO_2 melting point from the CO_2 triple point, which ranges from -62 to -63°C. The determination of individual inclusion composition by Raman microspectrometry has shown the maximum quantity of hydrogen sulfide up to 30 mole % in specimen Danilovskaya 22. The inclusions that have a melting point of CO_2 equal to -57 to -58°C contain no more than 2-3 mole % total of H_2S, CH_4 and N_2 (see table).

H_2O-CO_2 inclusions range from several micrometers to >100 µm. The inclusion shape corresponds to the negative halite crystal except for the specimens of the well Zayarskaya, where the inclusions of this type have a rounded shape (Fig. 3a,b). Sometimes solid authigenic carnallite and/or xenogenous solid phases are observed in the inclusions. H_2O-CO_2 inclusions are frequently either located in a chain or surrounded with an aureole of the single-phase aqueous brine microinclusions of some micrometers size. A different extent of inclusion fill as well as a wide range of Th CO_2 indicate inclusion trapping from a heterogeneous medium.

Inclusions with [that trapped] supersaturated brines are exceptional among H_2O-CO_2 inclusions in morphology. They look like solid-gas inclusions because of precipitation of a metastable solid phase that forms a complicated dendritic framework in the CO_2 phase (Bakhtinskaya well No. 1, Fig. 3c). When heating to 30-40°C, the solid phase dissolves and the solid-gas inclusion assumes the shape of a common H_2O-CO_2 inclusion. Sometimes the inclusions classified as essentially gaseous by optical investigation assume a similar shape on cooling due to precipitation of a solid phase from an invisible brine film. The [newly]-formed metastable solid phase does not disappear on heating back to room T.

*Analyses have been carried out on the following Raman spectrometers: (1) "OMARS-89" (Inst. Geology and Geophysics, Novosibirsk, USSR); (2) "MOLE" (CREGU, France); (3) "Microdil-28" ([Vrije] Univ., The Netherlands).

Brine inclusions in metamorphic halite occur both directly on the contacts with trap bodies and at various distances from it. Much less H_2O is typical of thermally metamorphosed specimens as compared with sedimentary-diagenetic halite. Not only does the total volume of aqueous phase decrease, but the size of the individual inclusions

Results of Raman spectroscopy of inclusions of condensed gases in metamorphosed halite.

No.	Area Name	*	Depth range (m)	Contents in mole %				
				CO_2	H_2S	CH_4	N_2	C_2H_6
1.	Tetenchiminskaya 1	(1)	2874	94.5	0.3	2.1	3.0	0.0
2.	Potassium deposit Nepskoye 13	(1)	742	99.9	0.1	0.0	0.0	0.0
3.	" " "	(1)	698	53.5	0.6	5.3	40.0	0.0
4.	Danilovskaya 22	(1)	1300	68.9	28.7	1.3	0.0	1.04
5.	Changuilskaya 188	(1)	1283	99.0	0.3	0.4	0.3	traces
6.	Mankurskaya 1	(1)	1494	100.0	0.0	0.0	0.0	0.0
7.	Bakhtinskaya 3	(1)	1663	100.0	0.0	0.0	0.0	0.0
8.	Sredne-Nepskaya 185	(1)	1183	100.0	0.0	0.0	0.0	0.0
9.	Chitorminskaya 165	(1)	2476-2483	100.0	0.0	0.0	0.0	0.0
10.	Yurubchenskaya 4	(1)	1865	97.3	2.3	0.0	0.0	0.0
11.	"	(1)	1875	97.1	2.9	0.0	0.0	0.0
12.	Nizhnetungusskaya 4	(2)	2706	98.0	0.6	0.0	1.2	0.0
13.	"	(2)		98.0	1.0	0.0	0.6	0.0
14.	Kochumdekskaya 3	(2)	2900	99.8	0.06	0.0	0.14	0.0
15.	"	(3)		99.7	0.1	0.2	0.0	0.0
16.	"	(3)		99.8	0.1	0.1	0.0	0.0
17.	"	(3)		99.8	0.1	0.1	0.0	0.0
18.	Gazhenskaya 116	(1)	841-936	97.3	1.5	1.3	0.0	0.0
19.	"	(1)		93.6	3.5	2.8	0.0	0.0
20.	"	(1)		98.0	1.0	1.0	0.0	0.0
21.	"	(1)		96.4	0.8	2.8	0.0	0.0

decreases. Microinclusions <10 µm in size occur in most specimens. They have a cubic shape and typically are arranged in curving chains. The inclusions are mainly one phase and sometimes contain sylvite crystals of an equal degree of fill [i.e., volume]. Rarely, one or two inclusions with a gas bubble or immiscible CO_2 liquid phase occur in a group of inclusions, indicating heterogeneous trapping.

The second type of brine inclusions contains saturated brines; they are usually round or, more rarely, cubic. They appear in two modifications which are mutually reversible by heating and cooling: one-phase brine inclusions and three-phase inclusions with a daughter phase and a gas bubble (Fig. 4). The inclusions often contain an ore phase along with one or more small crystals of other xenogenous solid inclusions. By heating to 30°C, the gas bubble and the solid daughter phase dissolve simultaneously but do not reform on cooling to room T. When cooling one-phase inclusions to -60 to -70°C, a solid phase and a gas bubble appear, which persist on heating to room T and dissolve only at 30°C, just as do the originally three-phase inclusions. The experiments described indicate that the bubble is a result rather of shrinkage than of inclusion cracking. The simultaneously formed solid phase indicates the presence of a supersaturated solution. Inclusions with supersaturated solutions are also found in salt xenolith[s?] from dolerite.

The investigations of inclusions in metamorphosed saline deposits gives solutions to a series of practical problems (Petrichenko, 1982). The metamorphosed halite specimens of the Siberian Platform are of great importance because of widespread trap inclusions in the saline the gas- and oil-bearing provinces. The inclusion investigation allows us to study the thermal aureole of intrusion influence, to estimate the degree of transformation of organic matter, to clarify the sources of sulfide mineralization, and to estimate the K content of the deposits.

Figure 1. Morphology of essentially CO_2 inclusions. a, c-g: at room T; b: at T = -20°C.

Figure 2. Histograms of CO_2 melting points and homogenization T in essentially CO_2 inclusions of specimens: 1—Nizhnetungusskaya-4 (2706); 2—Tetenchiminskaya-1 (2874); 3—Verkhnekatangskaya-3 (2559); 4—Kochumdekskaya-3 (2900); 5—Danilovskaya-4 (1865); 7—Chitorminskaya-165 (2476); 8—Srednenepskaya-185 (1183); 9—Kholokitskaya-1 (2549); 10—Changuilskaya-188 (1283). [Note: Dr. Grishina has added a few additional data to this diagram that are not present in the figure as published; they do not change the overall picture.]

Figure 3. $H_2O–CO_2$ inclusions. a: at room T (Yurubchenskaya-4, 1865); b: at -15°C; c: inclusions with a metastable solid phase at room T.

Figure 4. Aqueous inclusion with a metastable solid phase and shrinkage bubble.

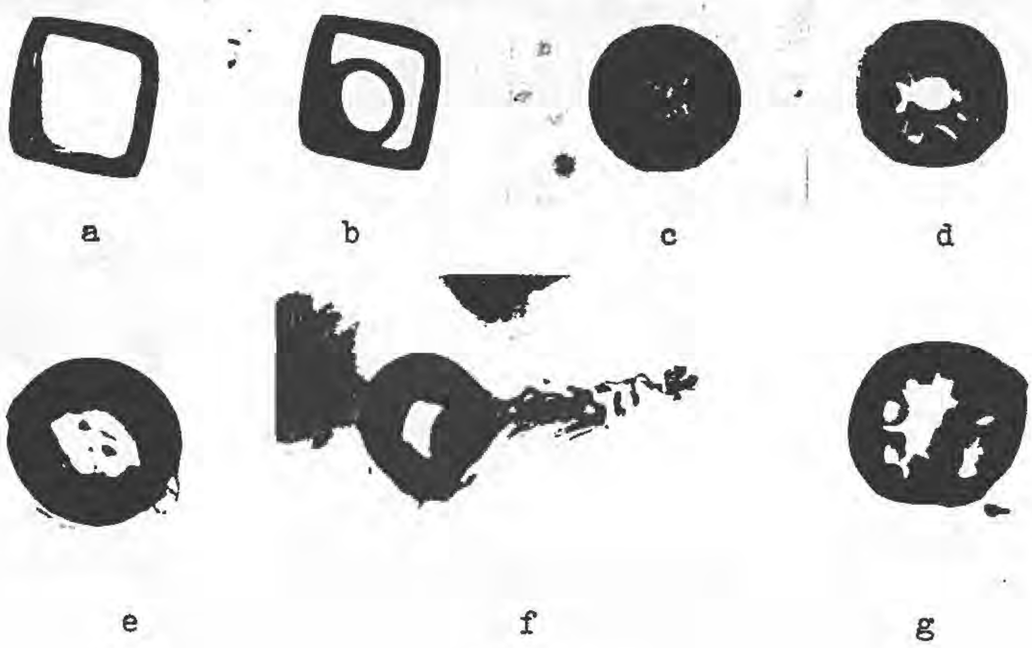


Figure 1

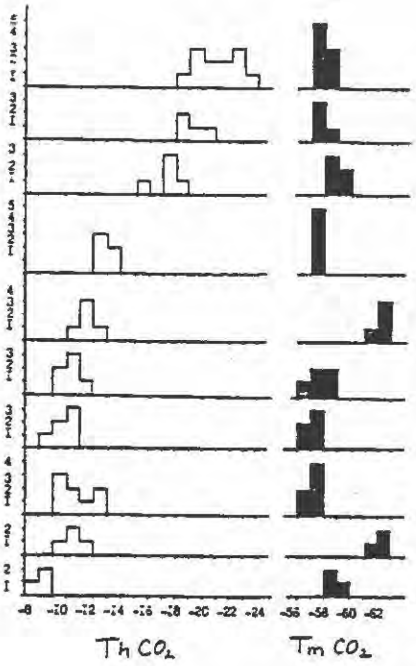
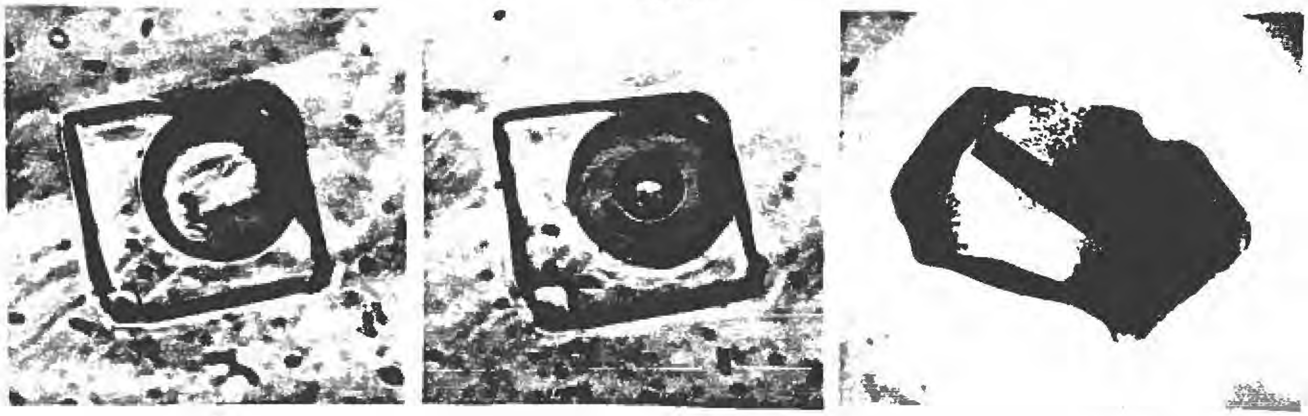


Figure 2



a b c

Figure 3

Figure 4

Lyakevich, Z.M. and Marushkin, A.I., On the interaction of igneous rocks with salt. *In* Lithology and Geochemistry of Salt-bearing Rocks: Kiev, 1980, p. 132-138.

Pavlov, D.I., Magnetite mineralization in which chloride waters participate. Nauka, Moscow, 1975, 245 pp.

Petrichenko, O.I., Physicochemical conditions of ancient salt accumulation and epigenesis of halogen sediments (from the data of investigations on inclusions in minerals). Author's doctoral dissertation in geological-mineralogical sciences: Lvov, 1982, 541 pp.

Petrichenko, O.I., Shaydetskaya, V.S. and Kovalevich, V.M., Inclusions in halite from veins in diabase. *In* All-Union Conference on Thermobarogeochemistry, Abstracts of Papers: Ufa, 1976, p. 59.

PORTNOV, A.M., VLASOVA, E.V. and KHITAROV, D.N., 1987, Pressure of CO_2 as a principal cause of ore transport and deposition in shallow gold-silver deposits: Geologiia Rudnykh Mestorozhdenii, v. 29, no. 4, p. 111-114 (in Russian, translated by Nora Tamburg, courtesy C. Cunningham).

The important role of the gas phase in material transfer and deposition processes in the course of geologic processes has been noted by various researchers. CO_2 assumes a special place among the natural gases. Its importance has been described by Naumov et al. (4): "Carbon dioxide (carbonic acid) and its salts act as weak electrolytes over the whole range of hydrothermal processes and as such assume the role of an acid buffer by regulating changes in pH and thus determining the behavior of all the other ions, including those of mineral elements. The ratio of carbon compounds of different valence determines the magnitude of the redox potential and regulates the behavior of all variable valence elements, including the activity ratios of sulfide and sulfate S and oxygen, which determine mineralization development." In other words, CO_2 , as the most abundant gas component in thermal solutions, exerts the most significant effect on pH and Eh values and their changes, providing conditions for transport and deposition of (mineral) components present in the mineralization environment.

The high concentration of CO_2 in vein quartz is considered to be a characteristic indicator, determining its ore content in Au-Ag deposits. Andrusenko et al. (1) cite a CO_2 content of 33 cm^3/kg for quartz-adularia associations and 63 cm^3/kg for quartz-adularia-chlorite. Efimova et al. determined up to 63.5 vol % CO_2 for Au ore manifestations in quartz-adularia ores. According to data of Goncharov and Sidorov (3), the sum of CO_2 and N_2 amounts to over 90% of the gas phase (nonaqueous) inclusions in minerals of all Au ore associations in deposits of the northeastern region of the U.S.S.R.

Thus, CO_2 concentrations determine the acid-base characteristics of solutions and activities of alkaline and ore elements. In turn, pCO_2 in solutions is regulated by the external P. Hence, determinations of pH in aqueous extracts of minerals in ore veins, which were measured in the laboratory under 1 atm P, stripped of CO_2, have little in common with the real pH of ore solutions, saturated with CO_2 at P exceeding 500 bar, and a corresponding highly acidic character.

Direct measurements of the relative CO_2 concentration, reflecting the pH of aqueous solutions, can be carried out by means of infrared spectroscopy. Such measurements were performed for ore and on-ore associations, as well as for varieties of zonally banded quartz of ore veins with Au-Ag deposits in volcanos at various location where quartz is the principal vein mineral. We studied associations of Au-adularia-quartz, Au-pyrite-sericite-quartz, calaverite-sericite-quartz, Au-acanthite-sericite-quartz, Au-antimonite-quartz, pale ores—of Au-quartz, argentite-adularia-quartz, and several others.

We studied plane parallel sections, 0.2-0.3 mm thick, cut from different sections of the ore veins. The size of the sections was up to 15-20 mm^2, the area of the "window," used for measurements, was 1-2 mm^2.

Infrared spectra were measured in the range of 2000-4000 cm^{-1}. By applying the diaphragm, we obtained

Table: Variation of gas concentration in quartz of an ore vein cross-section (mole/kg H_2O) and ratios of absorption intensities of CO_2 (2360 cm^{-1}) and Si-O (2250 cm^{-1}).

Location of quartz in vein	H_2*	H_2*	CH_4	C_2H_4	C_2H_2	CO	CO_2	H_2O, %†	$\frac{I\ 2360\ cm^{-1}}{I\ 2250\ cm^{-1}}$
Hanging wall contact	0.4	2.0	0.2	0.1	0.05	0.3	5.3	0.15	0.9-1.4
2 cm fr. contact	0.2	1.0	0.2	0.1	0.04	0.3	4.5	0.11	
5 cm fr. contact	-	2.0	0.2	0.1	0.05	0.3	2.3	0.11	
6 cm fr. contact (Center of vein)	0.2	5.2	0.1	0.1	0.04	0.4	**	0.11	0.5-0.6
Foot wall, 5 cm fr. contact	0.8	0.3	0.5	0.3	0.3	0.2	1.3	0.11	
3 cm fr. contact	0.2	0.7	0.1	0.05	0.02	0.1	0.6	0.06	
2 cm fr. contact	0.3	1.2	0.3	0.2	0.1	0.2	1.4	0.09	
Contact of foot wall	0.3	4.2	0.1	0.1	0.07	0.3	1.1	0.11	0.8-1.2

*Typo in original—presumably H_2 and N_2? **Not analyzed, interference by presence of calcite.

†% of weighed sample.

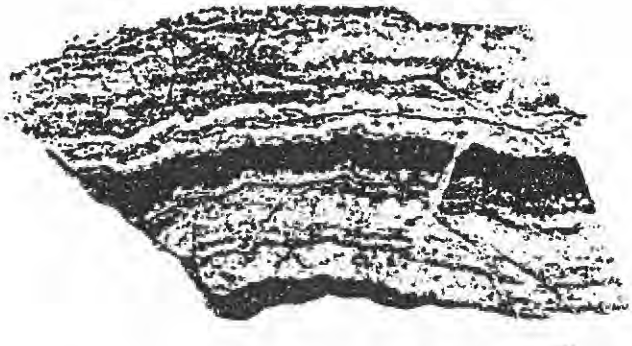


Figure: Zoned ore vein with ore mineralization. At the periphery of the vein the quartz is enriched with CO_2; adularia and ore minerals are absent. The ore deposit zone (black) is symmetrically bordered by zones of quartz-adularia associations, where the CO_2 concentration is much lower (half size).

spectra of narrow-banded sectors of sections, not to exceed 1x2 mm, which allowed us to follow the changes in CO_2, H_2O and OH composition in narrow zones, i.e., in sequentially changing generations of vein quartz, located in one section. Generally, this information is obtained in the form of averages over simultaneously obtained data from relatively large sections (5x20 mm).

All analyzed samples of zoned vein quartz belong to the low-temperature type and are characterized by intensive H_2O absorption bands with a maximum near 3400 cm-1, which often masked the presence of OH-group absorption bands. The following absorption bands were noted (in cm-1): 2360 (CO_2), 3240-3290 (H_2O), 3310 (OH-Al), 3410 (OH-K), 3440 (OH-Li), 3460-3470 (OH-K), 3490 (OH-Li), 3520 (OH-Li), 3550 (OH-K), 3590 (OH-K), 3620 (OH-K).

The IR-spectroscopy data were verified by analyses of vein quartz, samples taken across the zones of the ore vein (see table). The gas analysis data are in agreement with those obtained from IR-spectroscopy.

Sequential scanning across zoned ore veins resulted in a characteristic pattern of the local CO_2 distribution in vein quartz—at the margin of quartz veins and the host rock, and in such sectors where deposition occurred in the vein of native Au and Ag, calaverite, acanthite, pale ore, pyrite, as well as adularia, sericite and other vein and ore minerals.

A determination of the relative concentration of CO_2 in chalcedony type or milky quartz of ore veins showed that the CO_2 distribution was rather uneven: There was a high concentration of CO_2 in the marginal (precontact) zone; the concentration was maintained in the direction towards the center of the vein, if the quartz was practically devoid of ore minerals. However, the quartz in the immediate deposition zone of Au, Ag, Au tellurides, and Ag sulfides differs sharply in terms of obviously decreasing CO_2 content from the externally undistinguishable quartz of ore veins. This transition is sharp; it is associated with the microzoning of banded quartz in ore veins and occurs over an interval of several millimeters (see figure).

The increased concentration of CO_2 in inclusions of barren quartz from ore vein selvages is reflected by the increasing ratio of CO_2 absorption intensity bands (2360 cm^{-1}) to the intensity of the compound frequencies Si-O (2250 cm^{-1}), characteristic for the quartz matrix.

It seems that during deposition of vein quartz at the margin (periphery) or ore veins, pCO_2 was high and silica was deposited from acidic solutions; under these conditions, soluble complexes of Au and Ag compounds remained stable. The loss of CO_2 as a result of decreasing external P during tectonic movement and fracturing was accompanied by increasing alkalization of solutions in which, owing to a deficit of anions and excess of alkali metals, solutions of K, Na, and Li hydroxides are spontaneously formed (high-alkaline medium).

The quartz-adularia association is primarily characterized by the absence of CO_2. A set of well-defined CO_2 absorption bands is typical for quartz-sericite and quartz-pyrite associations; apparently in this case, the acidity of solutions has been increased for quartz sectors with adularia and Au-Ag mineralization. Since high concentrations of CO_2 (to 50-70 cm^3 per 1 g of quartz) have been repeatedly observed for vein quartz minerals, this served as the basis for using the determination of CO_2 by means of IR-spectroscopy in quartz minerals as a prospecting indicator (2).

It should be noted that the data have been obtained from samples of ore veins which were simultaneously used for analyses of externally homogeneous milky vein quartz. The analysis of platelets along the cross section of the ore veins has demonstrated the necessity of combining the "bulk" analyses of the different quartz generations, which differ in terms of extremely uneven CO_2 distribution over the range of the same ore vein. Hereby, it remained unnoticed that the CO_2 concentration decreased in inclusions in ore-bearing and adularization zones.

Thus, we conclude that high pCO_2 significantly determines the acidity of hydrothermal solutions and their capability of transporting complexes of Au, Ag and other metals, which are stable in acidic medium. The loss of CO_2 is accompanied by increasing activity of alkaline metals, primarily of K, increasing alkalinity of solutions, decomposition of soluble heavy metal compounds, and massive precipitation of native metals or their sulfide and telluride compounds.

Consequently, the formation of a commercial-grade Au-Ag association corresponds to zones with a steep P gradient (fractured structures), where degassing, boiling, and alkalinization of hydrothermal solutions takes place. As a result, a characteristic association of K metasomatites is formed, containing quartz-adularia and quartz-adularia-sericite, which are often accompanied by Au-Ag mineralization.

IR-spectroscopy of vein quartz contributes to the identification of CO_2 (P) gradient zones. This method may be applied to the analysis of samples taken from oxidation zones of ore veins, where sulfide minerals have been leached and the concentration of noble metals may have been significantly lowered.

(1) Andrusenko, N.I. (1980) Thermobarochemical formation conditions of gold-silver mineralization in shallow-seated deposits of the USSR. In Thermobarochemistry and Ore Genesis. Vladivostok, p. 105-110.

(2) Barkhudarian, N.B. and Grebenchikov, A.M. (1974) Application of the infrared spectroscopy method to the study of quartz of gold ore deposits. In TSNGRI Trudy. Moscow, vyp. 112.

(3) Goncharov, V.I. and Sidorov, A.A. (1979) Thermobarogeochemistry of volcanogenic ore formation. Moscow: Nauka, 206 pp.

(4) Naumov, G.B., Mironova, O.F. and Naumov, V.B. (1975) Carbon compounds in hydrothermal quartz inclusions. In Carbon and Its Compounds in Endogenic Mineralization Processes. L'vov, p. 3-4.

INDICES

The user should keep in mind the following features of these indices. The indexing procedures and entries are continuously evolving and hence are *not* uniform from one volume of Fluid Inclusion Research to the next, and even within a given volume, consistency cannot be claimed. The number of entries has been reduced this year, and *in many entries, only the more significant items are listed.* Where several different items in the given category occur on the same page, the number of such items (or "x," for multiple entries) is put in parentheses after the page reference. Some items may continue on to following pages.

Subject Index

See general notes above. I have tried to make this a user-oriented index rather than a documentalist's type index. Only data in the title and abstract are indexed, and then only if they appear to be of more than incidental mention. Misleading or erroneous translations may have resulted in occasional incorrect or omitted entries. Some entries are included under a given appropriate subject heading even though the index word does not occur in the abstract. The aim has been to err on the side of completeness and convenience to the user. Thus, I have attempted to index some related or possibly pertinent items, and even ones involving negative data or evidence, under each category. The ore-type terms such as porphyry copper and Mississippi Valley are used loosely. The deposit type is indexed only where it is evident without research. Analyses for specific elements are indexed only when they are particularly unusual or significant; thus, semiquantitative spectrographic analyses and statements of analyses as "Na-Ca-Cl fluids" are generally ignored. The mineral host for the inclusions studied is indexed except for quartz and decrepitation studies. Entires that would include too many page references are listed without page numbers. Some entries with broad and diffuse applicability have only a few of the most pertinent page references.

Locality Index

Notes: See page 424. Individual deposit place names are indexed only when significant data are presented. Inexact place names (e.g., "Soviet Far East") are not entered, nor are individual mines in districts known by a district name, although some may be so entered, in error. Cyrillic (and Chinese) place names are listed as they were given in the origin transliteration; various transliteration procedures yield different spellings: Began and Began'skii, Blyava and Blyavinsk, Kochkar and Kochkarskoje, Volhynia and Volyn, Kirin and Jilin. Names starting with Mt., Monte, and Mount are alphabetized exactly as spelled.

ERRATA

TEXT

Volume	Page	Item	Line	Change
11	238	3 & 4	-	Change first author to KHIN, Zaw and move to p. 102
16	297	1	1	Change authors to KHIN, Zaw and KHIN, M.T., and move to p. 132
17	272	2	15	Change "Ca-rinnerite" to "Ca-rinneite"
19	405	4	4	Change "p. 27" to "v. 27"
19	454	6	-	Change author to KERKHOF, A.M. van den, and move to p. 210
20	389 390	2, 3 2	-	Change author to KERKHOF, A.M. van den, and move items to p. 193
21	17	2	8	Change "p. 18" to p. 16-17
21	197	2	1	Change second author to GONEVCHUK
21	319	5	-	See also same authors, v. 19, p. 360-361
21	409 410	2 2	- -	Change author to KERKHOF, A.M. van den, and move items to p. 188
21	447	4	1	Change author to KHIN, Zaw, and move to p. 191
21	448	2	1	Change first author to THAN, Zaw, and move to p. 392
21	501	-	-	After "Cornubian Sn-W," delete "No. Pennine Orefield"
21	505	-	-	After "Northern Pennine Pb-Zn," add p. 404
22	245	2	-	Delete—duplicated in correct position on p. 252