FLUID INCLUSION RESEARCH

Edwin Roedder, *Editor*

Andrzej Kozłowski and Harvey E. Belkin,
Associate Editors

Volume 21
1988

H E Belkin

Fluid Inclusion Research

Volume 21

Camera-ready copy for this volume
has been provided by the editor

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SPECIAL NOTICE

Starting with the next volume, Volume 22 (1989), publication and order fulfillment will be transferred from Michigan to Virginia, and the price will be reduced to U.S. $20.00/volume, postpaid if payment received in advance. Standing subscription orders will be given a 20% discount. (Back issues will continue to be available as listed above.) Orders for Volume 22 onward should be addressed to:

Fluid Inclusion Research Business Manager,
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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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FLUID INCLUSION RESEARCH

VOLUME 21
1988

Edwin Roedder, *Editor*
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Associate Editors

ANN ARBOR
THE UNIVERSITY OF MICHIGAN PRESS

ISBN 0-472-02021-8
Published in the United States of America by
The University of Michigan Press
Manufactured in the United States of America

Preface

The purpose of these volumes is to provide entree to 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 1415 abstracts, citations, or annotated citations total, including 183 from the Russian, 36 from the Chinese, 84 from 11 other languages, and 54 from theses. Translations of titles and abstracts were provided by D.A. Brown (Canberra, Australia); J. Dubessy (Nancy, France); C.J. Eastoe (Tucson, AZ); 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); H.A. Stalder (Bern, Switzerland); T.M. Sushchevskaya (Moscow, USSR); and S. Takenouchi (Tokyo, Japan), and, of course, Associate Editor Kozlowski. Translations of full articles were obtained from D.A. Brown (Canberra, Australia); S. Grishina (Novosibirsk, USSR); and Kozlowski. These translations represent an enormous contribution toward achieving the aims of <u>Fluid Inclusion Research</u>. <u>Chemical Abstracts</u>, 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); L. Baumann (Freiberg, GDR); M. Fleischer (Smithsonian Institution, Washington, DC); A. Gize (Manchester, UK); J. Guha (Chicoutimi, Québec); J. Hedenquist (Tsukuba, Japan); M.J. Logsdon (Denver, CO); B.E. Nesbitt (Edmonton, Alberta); and R. Thomas (Potsdam, GDR). 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 (U.S.G.S.) for the bulk of 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.

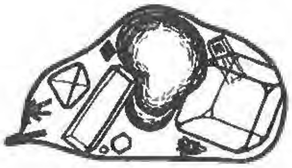
First, it is necessary that the desired items be in the database. Although several extensive geological literature computer databases have been consulted here, each such search nets only a few items not previously found, but most important, each produces only a small fraction of the entries found in an 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 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.

September 1, 1989 — Edwin Roedder, Editor

P.S. With Volume 20 (1987), the University of Michigan Press found it necessary to double the price from $15 to $30 per volume. As a result of this increase, we have decided to change publishers, starting with the next issue, Volume 22 (1989), and at that time will drop the price back to $20 per volume. See **IMPORTANT CHANGES** (page vi) for details.



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Editor's Special Request to Users

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 nonprofit 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 key word or author. You can help us make these planned actions as useful as possible by telling us what index entries and/or key words would be most useful to you, and also what would be your computer hardware/software requirements or limitations.

September 1, 1989

Edwin Roedder, Editor
Dept. Earth & Plan. Science
Harvard Univ., Cambridge, MA 02138

Notices of Meetings and Symposia

Past Meetings

The 7th All-Union Conference on Thermombarometry and Geochemistry of Mineral-Forming Fluid was held 30 September to 2 October, 1985. The abstracts of the papers from this meeting were published in two volumes (see Kalyuzhnyi, 1985, Fluid Inclusion Research, Vol. 18, p. 194) and translations were printed in Vol. 18, 1985, and Vol. 19, 1986. Full papers corresponding to some of these abstracts were published in 1988 in two books, but with a number of bibliographic complications; see two entries for Kalyuzhnyi, Bratus', et al., 1988, in this volume.

A seminar on "Applied thermobarogeochemistry," was held, sponsored by the Kazakh Acad. Sci. on June 2-4, 1987, at Alma-Ata, USSR. Very little information was available about this meeting until the publication of two volumes of short papers in 1988. Only two of these papers are abstracted here (see Dolgov, 1988, and Kormushin, 1988a); the remainder will be cited or translated in Vol. 22 (1989).

A meeting was held 2 November, 1988, of individuals interested in cathodoluminescence and ultraviolet microscopy (CL & UVM) at the annual meeting of the Geol. Soc. America. Volume 1, number 1 of a Newsletter has been published by the newly formed Soc. of Cathodoluminescence and Ultraviolet Microscopists (name subject to change). Interested individuals contact Dr. Otto C. Kopp, Co-editor, Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996-1410.

The 66th Annual Meeting of the German Mineralogical Society was held in 1988 at Bonn, FRG. Pertinent abstracts will be found in this volume.

The 2nd Biennial Pan American Conference on Research on Fluid Inclusions (PACROFI) was held in Blacksburg, Virginia, 4-7 January, 1989, with 99 registrants from 9 countries. Sixty-six oral papers and posters were presented. The abstracts for these will be in Vol. 22 (1989); copies of the volume of Abstracts of the Meeting are available from Dr. R.J. Bodnar, Dept. Geol. Sci., VPI&SU, Blacksburg, VA 24061. A special session of 14 papers devoted to microanalysis was held. A portion of the papers will be published as a group in Geochimica et Cosmochimica Acta.

There was a meeting of the Geologische Vereinigung in Leoben, Austria, 15-18 February, 1989, with 10 papers presented on fluid inclusions in ore deposit research. These abstracts will be in Vol. 22 (1989).

The 28th Int'l Geological Congress met in Washington, D.C., 9-19 July, 1989, with ~5900 registrants. Numerous abstracts from the 1858 pages of Abstracts Volumes 1-3 involve fluid inclusions and will be found in Vol. 22 (1989). (A planned workshop on fluid inclusions at the meeting was cancelled.)

ECROFI X, the 10th meeting on European Current Research on Fluid Inclusions, was held at Imperial College, London, April 6-8, 1989. A total of 86 oral and poster papers were presented; abstracts of these will be found in Vol. 22 (1989).

The Int'l Assoc. of Volcanology and Chemistry of the Earth's Interior held its General Assembly on Continental Magmatism in Santa Fe, New Mexico, June 25 - July 1, 1989. Among the hundreds of papers, a dozen or so deal with inclusions; abstracts of these will be in Vol. 22 (1989).

The 6th Int'l Symposium on Water-Rock Interaction was held August 3-12, 1989, in Malvern, UK. Abstracts of pertinent papers will be in Vol. 22(1989).

The Acad. Sciences of the DDR held the 5th Working Meeting on Isotopes in Nature, 25-29 September, 1989, in Leipzig, DDR.

The 13th Int'l Geochem. Exploration Symp. and 2nd Brazilian Geochem. Congress was held 1-6 October, 1989, in Rio de Janeiro, Brazil.

Future Meetings

The 3rd Int'l Symp. on Experimental Mineralogy, Petrology and Geochemistry will be held April 5-7, 1990, in Edinburgh. Contact Dr. G. Biggar, Dept. Geology, Univ. Edinburgh, W. Mains Rd., Edinburgh EH9 3JW, UK.

The 2nd V.M. Goldschmidt Conf., 3-5 May, 1990, sponsored by the Geochemical Soc., will be held in Maryland. Contact Peter Deines, General Chairman VMG-2, Dept. Geosci., Pennsylvania State Univ., 204 Deike Bldg., University Park, PA 16802, USA.

PACROFI III will be held in Toronto, Canada, May 20-23, 1990. For details contact Dr. E.C.T. Spooner, Dept. Geology, Univ. Toronto, Toronto, Canada M5S 1A1.

The 15th General Meeting of the Int'l Mineralogical Assoc. will be held 12-17 July 1990, in Beijing, China. A symposium on fluid inclusions is planned. For details, contact: IMA 1990, Dr. Wang Zejiu, Chinese Acad. Geol. Sci., Baiwanzhuang Rd. 26, FuWai, Beijing 100037, PRC.

The 8th Int'l Assoc. on the Genesis of Ore Deposits Symp. will be held 12-18 August, 1990, in Ottawa, Ontario, Canada. A session on fluid inclusions is planned. For details contact L.M. Cumming, Secretary, 8th IAGOD Symp., Geol. Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada.

An Int'l Symp. on Geochemical Prospecting will be held in late August 1990, in Prague, ČSSR. For details, contact: Symp. on Geochem. Prospecting, Geol. Survey (UUG), Malostranske nam 19, 118-21 Praha 1, ČSSR.

The Int'l Volcanological Congress (IAVCEI) will be held 3-8 September, 1990, in Mainz, FRG. For details, contact: Int'l Volc. Cong., Max-Planck-Inst. für Chemie Abt. Kosmochemie, Dr. G. Brey, Saarstrasse 23, D-6500 Mainz, FRG.

The 68th meeting of the German Min. Soc. will be held September 10-13, 1990, Würzburg, FRG. Contact Prof. Dr. M. Okrusch, Min. Inst. der Univ., Am Hubland, D-8700 Würzburg, FRG.

The 7th Int'l Conf. on Geochronology, Cosmochronology and Isotope Geology will be held 24-29 September, 1990, in Canberra, Australia. Correspondence to: ICOG 7 ACTS, GPO Box 2200, Canberra ACT 2601, Australia.

The 6th meeting of the European Union of Geosciences, EUG VI, will be held March 24-28, 1991, in Strasbourg. Contact Org. Comm. EUG VI, Univ. Trieste, Inst. Min., Piazzale Europa 1, I 34100 Trieste, Italy.

ECROFI XI, the 11th meeting on European Current Research on Fluid Inclusions, is tentatively scheduled for Spring, 1991 , in Florence, Italy; for details contact Dr. Pierfranco Lattanzi, Istituto di Mineralogi, Petrog. e Geochim., Univ. di Firenze, via G. La Pira 4, 50121 Firenze, Italia.

The 29th Int'l Geol. Congress is scheduled for Japan in 1992.

IMPORTANT - CHANGES IN PUBLISHER AND PRICE

Starting with the next issue, Volume 22, for 1989, publication and order fulfillment of Fluid Inclusion Research will be transferred from the University of Michigan to Virginia Polytechnic Institute and State University (VPI&SU), and the price will be lowered. The new price will be $20.00 per volume, postpaid if payment received in advance. Standing subscription orders will receive a 20% discount (i.e., $16.00 per volume), and previous standing orders will be transferred automatically. All future subscription correspondence should be sent to:

Fluid Inclusion Research
Department of Geological Sciences
VPI&SU, Blacksburg, VA 24061, USA

Back issues, Volumes 6 onward, $25.00 each (20% discount for complete sets Volumes 6-20), still available from:

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Ann Arbor, MI 48106, USA

Reprints of Volumes 1 (1968) through 5 (1972), $10.00 per volume, postpaid (20% discount for complete sets Volumes 1-5) still available from:

Edwin Roedder, Editor
Fluid Inclusion Research
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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.

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Vernadsky Inst., Acad. Sci USSR,
Kosygin St. 19, Moscow 117334,
USSR

Microthermometry Abbreviations

A consensus of fluid inclusion workers on usage of microthermometric terms was reached and first printed in Vol. 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, as pointed out by A.M. Van Den Kerkhov (personal communication, 1989).

Tt - The temperature of trapping, i.e, the temperature of formation of the inclusion. Thus Tt = Th 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 CO_2-H_2O (CO_2).

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 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 incorrectly used for NaCl dm-bearing inclusions to signify total apparent NaCl content by combining measurements of size (or Tm) of NaCl dm and an assumption as to NaCl concentration of solution at room temperature.

Abbreviations

The Cyrillic sequence,а,б,в,г,д,е is converted to abcdef. Other than the normal scientific and reference abbreviations, we use mainly the following:

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

*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 <u>pressure</u>. 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).

Abstracts and Citations, 1988

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 initials are listed as in the original. Differences in the transliteration procedures that are used in various Western journals for Cyrillic 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.) 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; names starting with "Mc" or "St" are alphabetized as though spelled "Mac" or "Saint." The difference in custom in the sequence of listing of surname between Spanish and Portuguese names 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.

AGAPOVA, G.F., SHMARIOVICH, Ye.M., VOROB'YEV, I.M. and KHITAROV, D.N., 1987, Experimental study of the behavior of molybdenum in hot sulfide-carbonate solutions: Geol. Rudnykh Mestor., 1987, no. 1, p. 77-86 (in Russian; translated in Int'l. Geol. Review, v. 29, no. 4, p. 491-498).

AGGARWAL, P.K., ADAMS, S., GUNTER, W.D. and KHARAKA, Y.K., 1988, The effect of pressure on aqueous equilibria (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). First author at Battelle/OWTD 7000 S. Adams, Willowbrook, IL 60521.

For most geochemical calculations, the effects of P on solution-mineral equilibria are estimated without considering the changes in ionization equilibria of aqueous complexes. This approach results in a significant overcorrection for the solubility of minerals, especially at higher T. We have used the relationship proposed by Marshall and Mesmer (1981; J. Sol. Chem) together with the "isocoulombic" form of reactions for estimating the ionization constants of aqueous complexes at high P. Estimates using this approach and 25°C value of ΔV of reactions satisfactorily reproduce experimental measurements of the ionization constants. Calculated saturation states of calcite in seawater at 100°C is ~500 (0.5 kbar) or ~800 cal (1.0 kbar) greater, and the T of calcite saturation is ~80°C (0.5 kbar) or ~40°C (1.0 kbar) higher, than the values obtained when the effect of P on ionization constants is neglected. Saturation states of calcite and anhydrite in subsurface waters from the Texas Gulf Coast may be overcorrected by ~1650 cal and ~650 cal, respectively, if the ionization constants are not corrected for P. (Authors' abstract)

AGGREY, K.E., MUENOW, D.W. and BATIZA, Rodey, 1988, Volatile abundances in basaltic glasses from seamounts flanking the East Pacific Rise at 21°N and 12-14°N: Geochimica Cosmo. Acta, v. 52, p. 2115-2119. First author at

Chem. Dept. & Hawaii Inst. Geophys., Univ. Hawaii, Honolulu, HI 96822, USA.

Volatiles in glasses from seamounts flanking the East Pacific Rise (EPR) in the vicinity of 21°N and 12-14°N were analyzed by high-T mass spectrometery. Compared to mid-ocean ridge basalt (MORB) magmas erupted at the spreading axis of the EPR at 21°N, the seamount magmas are commonly enriched in H_2O, Cl, F and S (at the same Mg#). Water and Cl abundances range from 0.111 to 1.021 wt.% and 0.003 to 0.226 wt.%, respectively. The wide range in abundances is consistent with the diversity of magmas erupted by these seamounts as indicated previously from major and rare-earth data. H_2O shows a strong linear positive correlation with K_2O content [$H_2O = 0.45 (\pm 0.04) K_2O + 0.22 (\pm 0.03)$ with RMS error of 0.09]. Based on H_2O/K_2O-ratios and K_2O abundances the glasses separate into three distinct groups: highly volatile-enriched alkalic/transitional, enriched tholeiitic, and depleted tholeiitic. Ratio-ratio plots of incompatible elements (La/Sm vs. K_2O/H_2O) indicate that these seamount magmas can all be related by the mixing of enriched and depleted source materials. (Authors' abstract)

AGGREY, K.E., MUENOW, D.W. and SINTON, J.M., 1988, Volatile abundances in submarine glasses from the North Fiji and Lau back-arc basins: Geochimica Cosmo. Acta, v. 52, p. 2501-2506. First author at Dept. Chem., Univ. Hawaii, Honolulu, HI 96822, USA.

Glasses from submarine lavas of the North Fiji and Lau back-arc basins were analyzed by high-T mass spectrometry for volatiles. Abundances for H_2O, Cl, F, S and CO_2 in glasses ranging in composition from depleted, primitive MORB to enriched, transitional tholeiites are reported. The samples divide into three groups based on K_2O vs. H_2O, Ba/Zr vs. H_2O and K_2O/H_2O vs. P_2O_5/H_2O variation diagrams. At similar Mg#, the least evolved samples studied are nearly identical to N-type MORB in H_2O abundances but show Cl contents enriched by a factor of 5. More enriched samples, classified as back-arc basin basalts (BABB) on the basis of major/trace elements and isotopes, are not as hydrous (at similar Mg#) as those from the Mariana and East Scotia Sea back-arc basins. The data indicate that not all back-arc basins erupt lavas with the distinct volatile and other elemental characteristics of lavas from the Mariana Trough and Scotia Sea. (Authors' abstract)

AHARON, P., LIEW, T.C., SINGH, I.B. and CHOWDHURY, A., 1988, An appraisal of the isotopic evolution of sea water at the terminal Precambrian (abst.): Terra cognita, v. 8, p. 216. First author at Max-Planck-Inst. für Chemie, Mainz, FRG.

Renewed interest in the isotope events of late Pecambrian has led to recent proliferation of high resolution isotope records acquired from sites that maintained continuous sediment deposition. The carbon isotope component of these records seems to suggest significant offsets prior to, or at, the designated Precambrian/Cambrian (PC/C) boundary. So far little attention has been given to the oxygen isotope evolution of the late Precambrian sea water, and the effects of post-depositional water-rock interaction on the integrity of the stable isotope records.

Here we report the results of a detailed carbon, oxygen and strontium isotope investigation of marine sediments in the Lesser Himalaya, India, which document the isotopic evolution of sea water across the PC/C boundary. The 700 m thick section contains relatively undisturbed planar stromatolites that were dolomitized on a regional scale. Archaeocyathid reefs and associated calcareous algal bioherms represent the first skeletalized fossil occurrences within the stromatolite-dominated sequence and constitute a pronounced biostratigraphic marker.

Evaluation of the isotope data based on early dolomite phases rules out post-depositional isotope exchange as a major control on the recorded C-13 and O-18 variations. By scaling the O-18 record to Tertiary dolomites of sea water provenance, we show that late Precambrian sea water was more depleted in O-18 by about 3‰ or, alternatively, it was 10 to 15°C warmer. Late dolomite phases are significantly more depleted in O-18 and C-13, and more enriched in radiogenic Sr-87 relative to the early dolomite phases and preserve the imprint of hot fluids of crustal provenance which advected through the sediments during burial. The linear relationship observed between O-18/O-16 and C-13/C-12 compositions of all dolomite phases does not offer evidence of primary dolomite precipitation from late Precambrian sea water, as proposed recently by Tucker, but attest to the conspicuous absence of soil-derived CO_2 prior ot the advent of organic soils. (Authors' abstract)

AISSA, Mohamed, 1987, Reconstruction of an ancient hydrothermal system, and its implications for metallogenesis: the District of Echassieres (French Massif Central) (abst.): PhD dissertation, Inst. Nat'l. Polytech. de Lorraine, France (in French; translated by R.P. Moritz).

The study of fluid inclusions trapped in various lithological units that were intersected by the drill hole Echassieres 1, in combination with a detailed study of the dike assemblage of La Bosse and its W-bearing mineralization, has permitted modeling of the hydrothermal evolution of the site in relation with the different magmatic events that have affected the area.

The model is composed of three main stages:

- The stockwork stage of La Bosse which can be subdivided into two phases: an early emplacement of quartz veins (and associated magmatic dikes), followed by the emplacement of the hypothetical Bosse granite, and the circulation of fluids rich in CO_2, CH_4, and N_2. These solutions have been diluted by aqueous fluids, and probably resulted in the precipitation of wolframite between 300 and 400°C. The second phase in the evolution of this stockwork is linked to the emplacement of the Beauvoir granite, and is characterized by early brines enriched in Li, F, Nb, ... In the stockwork, it resulted in local dissolution of quartz, and in precipitation of topaz and Li-bearing mica. These fluids also reacted with wolframite, produced solid wolframite-columbite solutions, and corroded the early crystals.

- The emplacement of the Colettes granite took place between 1000 and 1200 bars, increased the T in its immediate environment (up to 600°C). In the stockwork, it resulted in physico-chemical modifications of the fluids with the highest densities ($d \sim 0.75$), including those responsible for the mineralization. The intrusion of the Beauvoir granite is responsible for the subsequent evolution of the area. P-T conditions are estimated to be in the range of 560 to 580°C, and 800 to 900 bars. This intrusion triggered off a major hydrothermal system. At the beginning, conditions changed from lithostatic to hydrostatic, and early magmatic brines were released. This even has been recorded in the host stockwork. Subsequently, the presence of fractures and thermal gradient developed around the Beauvoir granite promoted the circulation of external fluids that diluted the magmatic brines. The introduction of external "cold" fluids is responsible for the cooling of the granite, thus for slowing down the fluid circulation, and the aging of the geothermal system of Beauvoir. (Author's abstract)

AKAGI, T. and MASUDA, A., 1988, Isotopic and elemental evidence for a relationship between kimberlite and Zaire cubic diamonds: Nature, v. 336, p. 665-667. Authors at Lab. for REE Microanalysis, Dept. Chem., Fac. Sci., The Univ. Tokyo, Hongo, Bunkyo-ku, Tokyo 113, Japan.

Cubic diamonds from Zaire contain fluid inclusions which may record the conditions under which the diamonds formed -- either in the mantle or in the kimberlite magma which transported them to the surface. Here we present Sr isotope ratios for whole cubic diamonds, and abundances of rare-earth elements, K, Rb, Sr and Ba for both whole cubic diamonds and the leachings from crushed cubic diamonds. The $^{87}Sr/^{86}Sr$ ratios of the diamonds range from 0.7038 to 0.7052, which is almost identical to that of Mbuji Mayi kimberlite. The chondrite-normalized elemental abundance patterns of the diamonds roughly resemble that of kimberlite but show more enrichment in incompatible elements. The bulk of the impurities are soluble in water. The results of the present study support the genesis of fluid inclusions in diamond in the kimberlite or in the source of kimberlite magma. (Authors' abstract)

AKAKU, K. and YAGI, M., 1988, Mineral precipitation from the saline geothermal water of the Fushime area, Kyushu, Japan: The precipitation process of anhydrite: Proc. The 10th New Zealand Geothermal Workshop, Univ. Auckland Geothermal Inst., 1988, p. 229-234. First author at Geothermal Div., Japan Petrol. Explor. Co., Ltd. (JAPEX) 2-17-22, Akasaka, Minato-ku, Tokyo 107, Japan.

Fluids in the Fushime geothermal system, Kyushu, Japan, are high-T (exceeds 300°C) and saline, which most likely originated from seawater-rock interaction. Anhydrite (scale) has been found in a specific zone of a production well where sulfate-rich low-T water is assumed to mix with ascending high-T sulfate-depleted water. To investigate the precipitation process of anhydrite, chemical compositions of the mixing end members were estimated and changes of chemical speciation with the mixing and boiling processes were calculated. The results show that the mixed waters are supersaturated with anhydrite only above 240°C, and this T range agrees with Th of fluid inclusions trapped anhydrite (scale) sampled from the well. This agreement indicates that the mixing model used here is reasonable in explanation of the precipitation process of anhydrite in the well. (Authors' abstract)

AKANDE, S.O. and FAKOREDE, O., 1988, Gold mineralization in the Nigerian schist belts (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 140-142. First author at Dept. Geol., Univ. Ilorin, Ilorin, Nigeria.

Preliminary fluid inclusion studies carried out on samples of quartz from the three districts gave Th between 90°C and 320°C. A bimodal distribution of T with a low T mode between 160 and 180°C and a higher T mode between 220 and 240°C were identified in the three districts. The Th populations are interpreted as representing at least two episodes of shearing, mineral deposition and recrystallization in the veins. [Tm ice] suggest a salinity of ~1.5 eq. wt.% NaCl for the ore solution. Clathration was observed between 2.0°C and 4.0°C in some of the inclusions due to the presence of unquantified CO_2 content. (From the authors' abstract)

AKANDE, S.O., HORN, E.E., and REUTEL, C., 1988, Mineralogy, fluid inclusion and genesis of the Arufu and Akwana Pb-Zn-F mineralization, middle Benue Trough, Nigeria: J. of African Earth Sci., v.7, no.1, p.167-180. First author at Dept. of Geol. and Min. Sci., Univ. of Ilorin, Ilorin, Nigeria.

Pb-Zn fluorite fracture-controlled veins occur at Arufu and Akwana within a carbonate sequence. The carbonate wall rocks are extremely silicified in areas adjacent to veins. Inclusions in fluorite yield Th from 106 to 148°C (avg. 132°C), P corrections should be minimal. Tm-ice yield values 15 to ca 23 eq.wt.% NaCl. Te data suggest very high values of $CaCl_2$ in the ore fluid. The low T of the ore forming fluid compares with the low T reported from the sphalerite and quartz inclusions in deposits to the south. Our results suggest mineralization resulted from heated $NaCl-CaCl_2-H_2O$ basinal brines; the "fluoritic subtype" of the Mississippi Valley Type (MVT) deposits. (From the authors' abstract)

AKANDE, S.O., MUCKE, A., UMEJI, A.C., 1988, Mineralogy, texture and paragenesis of the Abakaliki-Ishiagu lead-zinc ± copper lodes (abst.): 24th Ann. Conf. Nigerian Mining and Geosciences Soc., p.2. First author at Dept. of Geol., Univ. of Ilorin, Ilorin [Nigeria]

The Abakaliki-Ishiagu Pb-Zn-Cu lodes are discordant fracture controlled bodies in shales, intruded by highly altered microdiorite sills. There are at least three main stages of evolution for the sulfide and sulphosalt minerals. Although our previous fluid inclusion studies suggest T of 117°C to 199°C (avg. 154°C) for the district, ore stage bornite twinning and anisotropy suggest that the ore fluids might have attained T≥225°C for the Sb and Cu minerals. Such high T is expected when ore forming fluids get hotter at deeper parts of the basin, hence their greater tendency to leach Cu and Sb ions at depth. The mineralogy and texture of lodes are comparable to those of the giant Navan Pb-Zn ore body in Central Ireland and appear to be related to rift environments. (From the author's abstract)

AKANDE, S.O., OLANIYAN, O., and OKONKWO, C.T., 1988, Palaeoenvironmental significance of marble deposits in the Nigerian schist-belts: 24th Ann. Conf. Nigerian Mining and Geosciences Soc., p.2, Authors at Dept. Geol. and Min. Sci., Univ. Ilorin, Ilorin, [Nigeria]

Geothermometric studies of calcite crystals in the Lokoja marble deposit (the largest in the belt) reveal avg. Th of 231.3°C for S inclusions without P corrections. Salinity ≈8 eq. wt.% NaCl. Oxygen isotope composition from the Lokoja deposit range from $\delta^{18}O$ SMOW 18.33‰ to 25.34‰ for calcite with a mean of 23.07 per mil. A heavy carbon isotope value averaging S^{13}[sic;$\delta^{13}C$ meant] CPDB 3.88 per mil was measured for this calcite. The oxygen isotope composition for the calcite imply a source fluid with $\delta^{18}O$ averaging 15.47 per mil at 231.3°C. This value clearly corresponds to typical metamorphic waters.

Our studies suggest that marble deposits in the Nigerian schist belts represent parts of the sedimentary basinal sequences deposited at the onset of their evolution. (From the authors' abstract)

AKANDE, S.O., and ZENTILLI, M., 1988, Fluid inclusion and trace element studies on the fluorite mineralization at Arufu and Akwana, Middle Benue Trough; Metallogenic significance (abst.): 24th Ann. Conf. Nigerian Mining and Geosciences Soc., p.3. First author at Dept. of Geol. and Min. Sci., Univ. of Ilorin, Ilorin [Nigeria].

See Akande, Horn, and Reutel, this volume. (E.R.)

AKHVLEDIANI, I.R., PORITSKAYA, L.G. and KOTOV, N.V., 1988, Thermodynamic conditions of zeolite formation in Cretaceous rocks of the eastern part of the Trialet Range: Soobshcheniya Akad. Nauk Gruzinskoy SSR, v. 130, no. 2, p. 369-372 (in Russian).

Indexed under "Fluid Inclusions." (E.R.)

ALBINO, G.V., 1988, Large-scale vertical metal zoning in Mother Lode-type systems (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abstract Series, no. 23, p. 303-305. Author at Dept. Geol., Univ. Western Ontario, London, Ontario, Canada N6A 5B7.

Fluid inclusions from the Mother Lode-type deposits considered here (Albino, unpub. data) have ice and clathrate melting T indicating the fluids were of negligible (<0.5% eNaCl) salinity. Au ores containing relatively abundant base metals occur in close association with Mother Lode-type deposits in some areas, and the fluid responsible for these deposits have higher salinities, from 3-6% eNaCl (Albino, 1986, Contrasting styles of gold mineralization in the Sierra Nevada metamorphic belt, California: in Chater, A.M. (ed.), Gold '86 Poster Volume, and in prep.). The extremely low salinity of fluids from Mother Lode-type deposits indicates that Au and other metals could not have been transported as chloride complexes, but were likely in the form of bisulfide complexes. (From the author's abstract by E.R.)

ALBINSON F., Tawn, 1988, Geologic reconstruction of paleosurfaces in the Sombrerete, Colorada, and Fresnillo districts, Zacatecas State, Mexico: Econ. Geol., v. 83, p. 1647-1667. Author at Grupo Catorce, S.A. de C.V., Paseo de las Reforma, No. 51, Piso 16, Colonia Revolucion 06030, Mexico, D.F.

Recent mapping has identified the paleosurfaces contemporaneous with the epithermal polymetallic vein systems of Sombrerete, Colorada, and Fresnillo, Zacatecas. Ag-Pb-Zn ore zones generally occur within the Mesozoic basement rocks, whereas the paleosurfaces are located within the overlying Tertiary volcanic pile. Stratigraphic reconstruction and fluid inclusion data predict hydrostatic or hydrodynamic fluid P, and depth from the paleosurface to mineralization. The Pabellon vein in the Sombrerete district lacks evidence for fluid boiling and the reconstructed depth to the top of mineralization is at least 1,000 m. However, for hydrothermal systems that operated along the liquid-vapor boiling curve (the Santo Niño vein in Fresnillo and the No Conocida vein in Colorada), depths to the top of mineralization of less than 500 m are indicated. Higher T and salinity fluids coincide with ore zones at depth, and fluids of progressively lower T and salinity occur in the high-level environment near the paleosurfaces. These trends most likely result from fluid mixing and dilution of ore-forming fluids circulating in the deeper parts of the systems, with meteoric waters of near-surface derivation.

Combined geologic and fluid inclusion data become useful exploration and development tools. On a district wide scale the identification of the paleosurface defines the highest level of a fossil hydrothermal system and can help to evaluate from the top downward the sectors of the district where economic potential remains preserved at depth. Recognition of the paleosurface and its expressions can aid in locating exploration targets in terranes not yet exposed at depth by erosion. (From the author's abstract by E.R.)

ALBINSON F., Tawn and PARRILLA P., L.V., 1988, Geologic, mineralogic, and fluid inclusion characteristics of polymetallic veins, Real de Guadalupe mining district, Guerrero, Mexico: Econ. Geol., v. 83, p. 1975-1984. First author at Grupo Catorce, S.A. de C.V., Paseo de la Reforma No. 51, Piso 16, 06030 Mexico, D.F., Mexico.

Fluid inclusion evidence of boiling is abundant. Th for the three vein stages are: I and IIa, sphalerite and quartz, 170-290°C, avg. 224-241; III 170-245; avg. 208°C. Salinities: I and IIa, ≤8 wt % eq. NaCl; III, ≤4 wt % eq. NaCl. Depths of formation, from salinity, Th and boiling conditions = ~300 m for stage I. (E.R.)

ALDERTON, D.H.M., 1988, Ag-Au-Te mineralization in the Ratagain complex, northwest Scotland: Trans. Inst. Min. & Met., v. 97, Sect. B, p. B171-B180.

A distinctive association of Ag-, Au- and Te-bearing minerals has been found in the Ratagain igneous complex, northwest Scotland. Fluid inclusion studies have indicated that CO_2-rich fluids of low to moderate salinity were associated with the mineralization. T of mineralization were probably in excess of 300°C. The fluids were also enriched in Na, Ca, K, Ba, Sr and S.

The similarity between fluid inclusion and host-rock chemistry (especially the high Ba and Sr contents) suggests a close association between the hydrothermal fluid and the igneous rocks. It is tentatively suggested that the fluids had a dominantly magmatic origin. The origin of the Au, Ag and other metals is less readily explained, but the association with alkaline igneous rocks seems particularly important. (From the author's Synopsis by E.R.)

ALEKHIN, Yu.V. and VAKULENKO, A.G., 1987, Thermodynamic parameters and solubility of NaCl in water vapor at 300-500°C up to 300 bar: Geokhimiya, no. 10, p. 1468-1480 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 5, p. 97-110). Authors at Experimental Mineral. Inst., USSR Acad. Sci., Chernogolovka, USSR.

Radioactive tracers have been used to obtain P-T-X data on the H_2O-NaCl system at 300-500°C and 10-300 bar. The entry of NaCl into the vapor phase involves hydration reactions. Thermodynamic functions have been derived for $NaCl \cdot 4H_2O$ in the vapor, which show moderate negative deviations from ideal behavior. Methods of chemical thermodynamics are promising in researching natural fluids. The transport of sparingly volatile components in the gas-type phase may be effective in the distribution of dissolved materials in hydrothermal systems. (Authors' abstract)

ALFARO, Guillermo and FRUTOS, José, 1988, Geochemistry of the massive sulfides and their country rocks from the Coastal Range, southern Chile: Mining Geol., v. 38, p. 15-25. Authors at Dept. Geosci., Univ. de Concepción, Concepción, Chile.

Fluid inclusion data (Th = 250-310°C) is presented for quartz from the Piren Alto deposit. However, the authors conclude that this T represents the subsequent metamorphic conditions. (H.E.B.)

ALMEIDA, Angela and NORONHA, Fernando, 1988, Fluids associated with W and Ag-Au deposits of the Mirandela area, NE Portugal: An example of perigranitic zoning: Bull. Minéral., v. 111, p. 331-341. Authors at Centro de Geol. da Univ. do Porto (INIC), Fac. de Ciencias, 4000 Porto, Portugal.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 6-7. (H.E.B.)

ALTANER, S.P., FITZPATRICK, J.J., KROHN, M.D., BETHKE, P.M., HAYBA, D.O., GOSS, J.A., and BROWN, Z.A., 1988, Ammonium in alunites: Am. Min., v.73, p.145-152.

ALTHAUS, E., 1988, Fluid-dependent processes and their documentation in fluid inclusions in rocks from the KTB (abst.): Min. Geol. of USSR Inter-Union Comm. on the Lithosphere Int'l. Seminar, "Super-deep continental drilling and deep geophysical research" abstracts, Aug. 23-29, 1988, p. 188-191.

A review, covering the origin, significance, and occurrence of fluids, and some of the procedures to be used for analysis of them. (E.R.)

AMUNDSEN, H.E.F., ANDERSEN, T. and BURKE, E.A.J., 1988, Trapped fluids associated with Cr-diopside-rich veins in spinel lherzolite xenoliths: Implications for mantle metasomatism (abst.): Chem. Geol., v. 70, p. 46. Authors at Mineral.-Geol. Museum, Sars gt. 1, 0562 Oslo 5, Norway.

The nature of fluids in the upper mantle has implications for element migration during metasomatic processes, the mantle solidus and oxidation state. The focus of this study are fluid inclusions associated with Cr-diopside-rich veins in spinel lherzolite xenoliths from northwestern Spitsbergen.

Two main types of primary textured inclusions occur: (1) high-density CO_2 fluid; and (2) glass + amphibole + CO_2 fluid. Microthermometric measurement and laser Raman microprobe analyses suggest that the CO_2 is pure or nearly pure. The recalculated bulk composition of type (2) inclusions resembles a volatile-rich high-Al basaltic liquid. This liquid is in equilibrium with the coexisting minerals at ca 1150°C, using experimental data on pyroxene- and olivine-liquid equilibria.

The microtextures and fluid inclusion data suggest that the Cr-diopside-rich veins formed by crystallization of pyroxenes during infiltration of immiscibly coexisting high-Al basaltic liquid and CO_2 fluid. Vein and lherzolite minerals have near identical compositions, indicating that the compositions of the infiltrating fluids were buffered by a spinel lherzolite (Fo_{90}) mineralogy. Thus, the infiltration process resulted mainly in an increase in the pyroxene/olivine ratio in the bulk lherzolites, leaving mineral compositions largely unchanged. Type (2) inclusions have also been found in spinel lherzolites showing high Ca/Al ratios, but otherwise no textural evidence of metasomatic enrichment. This suggests that spinel lherzolites with anomalously high pyroxene contents may reflect metasomatic processes similar to those represented by the pyroxene rich veins. (Authors' abstract)

ANASTASENKO, G.F., APLONOV, V.S., KAPLUNOV, L.S. and SURIKOVA, A.S., 1988, The thermobarogeochemical conditions of formation of the Oshurkovsk apatite deposit (Buryatia), in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 238-241 (in Russian).

ANDERSEN, Tom, 1988, Origin and significance of fluid inclusions in matrix minerals in carbonatites, a case study from the Fen carbonatite complex, Norway: Geol. Soc. India Memoir 11, p. 25-36. Author at Mineral.-Geol. Museum, Univ. i Oslo N-0562 Oslo 5, Norway.

The carbonatites in the Fen complex, S.E. Norway, contain fluid inclusions in two different microstructural settings: (1) early inclusions in relict apatite crystals within cumulate xenoliths in the carbonatites and (2) inclusions of unclear textural status in matrix calcite. Inclusion group (1) was shown earlier to be of mid-crustal, magmatic origin (Andersen 1986). Inclusions of type (2) are indistinguishable from the former group in terms of composition, and have overlapping or marginally higher densities, apparently suggesting a similar deep origin. Independent geological evidence, however, requires these inclusions to have formed in-situ, in the shallow crust. This is feasible only at sub-solidus T of 200-300°C. The consequence of these findings for the applications of fluid inclusion data to carbonatites is discussed. (Author's abstract)

ANDERSON, A.J., CLARK. A.H., MA, X.-P., MacARTHUR, J.D., and PALMER, G.R., 1988, Proton microprobe investigations of fluid inclusions in quartz from the Panasqueira W (-Sn, Cu) deposit, Portugal (abst.): GAC/MAC Program with Abstracts, v.13, p.A2. First author at Dept. of Geol. Sci., Queen's Univ., Kingston, Ontario, K7L 3N6, Canada.

Unopened liquid-rich fluid inclusions in quartz from the Rebordões section of the ca. 295 Ma Panasqueira deposit were non-destructively analyzed by proton-induced gamma- and X-ray emission methods (PIGE and PIXE, respectively). These "type 1" inclusions (Kelly and Rye, 1979) consist of a relatively low-salinity (5-11 wt.%), NaCl-dominated brine plus a CO_2 vapor/liquid phase, and commonly contain apparent dxl of muscovite and tourmaline. The inclusions are large (up to 300 μm), permitting easy targeting, and hence proved suitable for our initial investigations of the effectiveness of PIGE/PIXE analysis of natural, undersaturated fluid inclusions. Five fluid inclusions (one containing a white mica) lying between 15 and 40 μm below the surface of the quartz plates were separately bombarded for 60 minutes with a 3.7 MeV proton beam having a spot size of 40-120 μm and a current of 1.0 to 1.5 nA. The gamma- and X-ray spectra were simultaneously collected using an EDS system with, respectively, Ge(Li) and Si(Li) detectors.

Our results show that PIXE is relatively insensitive for light elements such as Na and Cl because the low-energy X-rays are highly attenuated by the overlying quartz. However, gamma-rays from the Na(pp'γ)Na nuclear reaction that were detected using PIGE indicate that Na is a dominant component in the fluid; this is consistent with previous analyses by a destructive analytical technique. Calculations to determine the Na concentrations are in progress. Comparison of the spectra obtained from the mica-bearing inclusions and from mica in the quartz vein indicates that both micas are F- and Fe-rich muscovites with similar major- and minor (Mn, Zn, Rb and Sn) element contents. (Authors' abstract)

ANDERSON, A.J., CLARK, A.H., MA, X.-P., PALMER, G.R., MACARTHUR, J.D. and ROEDDER, E., 1988, Application of the micro-PIXE/PIGE method to nondestructive, in situ, analysis of fluid inclusions in ore deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A142. First author at Dept. Geol. Sci., Queen's Univ., Kingston, Ontario, Canada K7L 3N6.

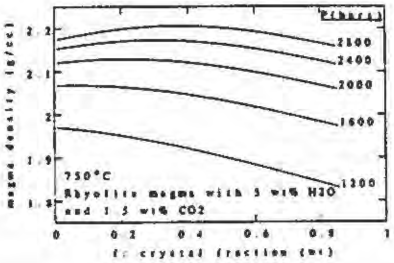
A microbeam of protons from a 4.0 MV Van de Graaff accelerator has been used to excite, simultaneously, characteristic gamma- and X-rays from a number of elements contained in unopened FI in minerals. The two analytical procedures, known as particle-induced X-ray (PIXE) and gamma-ray (PIGE) emission, are based on different principles and are applied to different elements. The PIGE method permits detection of light elements such a Li, Be, B, F, Na, Mg and Al. Its sensitivity to a particular element in an inclusion is dependent on: 1) the energy of the incident protons within the inclusion; 2) the dimension of the inclusion traversed by the beam; and 3) the gamma-ray production cross-section for the element of interest. The PIXE method is used to analyze elements with Z >10. Its detection limits are significantly affected by X-ray absorption by the host mineral, which varies according to: 1) the energy of the fluorescent X-rays; 2) the host mineral density; and 3) the depth of the inclusion below the surface.

In the present study, data were obtained from FI in quartz from the Bingham porphyry Cu deposit, Utah, and the Panasqueira W deposit, Portugal, and in spodumene from the Tanco rare-element pegmatite, Manitoba. PIXE data on highly-saline inclusions from Bingham confirm the presence of S, Cl, K, Ca and Fe, and permit estimates (ppm) of: Fe 28000, Mn 1700; Cu 1800; Zn 700; Pb 700; and Br 200. Na was detected by PIGE. PIXE spectra obtained from low-salinity inclusions from Panasqueira did not show the presence of Na or Cl, presumably owing to signal attenuation. However, Na was detected by PIGE. A mica-bearing inclusion from Panasqueira revealed F, Na, and Al (PIGE), and K, Ti, Mn, Fe, Cu, Zn, As (or Pb), Rb and Sn (PIXE). Analyses of two crystal-rich inclusions in spodumene from Tanco was complicated by signals from Li, Al and Si in the matrix. Nevertheless, a daughter crystal originally thought to be the new mineral diomignite ($Li_2B_4O_7$) was shown to contain major amounts of Ca but no detectable B.

Although these data are preliminary, they demonstrate the great potential of the micro-PIXE/PIGE method for FI studies. Considerable instrumental improvements are anticipated to optimize the sensitivity and analytical accuracy of the technique. (Authors' abstract)

ANDERSON, A.T., Jr., NEWMAN, Sally and STOLPER, E.M., 1988, Density changes caused by gas-saturated crystallization: Implications for stratification in silicic magmas (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A248. First author at Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637.

Interpretation of H_2O and CO_2 analyses of glass inclusions in quartz phenocrysts from the Bishop Tuff rhyolite suggests that its magma was saturated with CO_2-H_2O vapor. At high levels in the magma, the coexisting vapor would have been nearly pure H_2O; at deeper levels, it would have been rich in CO_2. We have modelled the course of closed system crystallization of a vapor-saturated magma with a bulk composition of 5% H_2O, 1.5% CO_2 over a range of P (see Figure). At P >1.5 kbar, bulk density (ρ)at first increases, then levels off, and finally decreases as the degree of crystallinity (f) increases. The maximum in ρ achieved during crystallization occurs at lower f for lower P, until at P <1.5 kbar, ρ decreases continuously from the onset of crystallization. The low P trend results because isobaric crystallization of anhydrous minerals from a magma saturated with a vapor rich in H_2O causes exsolution of large amounts of low density vapor. However, at the higher P where the vapor is richer in CO_2, crystallization initially only slowly increases the proportion of vapor in the magma; the intial increase in ρ calculated under these conditions reflects the increased proportion of the high density crystalline fraction of the magma. With continued crystallization at high P, the water content of the melt increases until further crystallization eventually results in transfer of water in large amounts to the vapor phase; this overwhelms the influence of increased crystallinity on ρ and results in a decrease in bulk density. Although the details depend on bulk magma composition, crystallization at shallow depths will always result in lower bulk density, whereas crystallization at greater depths produces a denser bulk magma initially. We thus conclude that crystallization of a vapor-saturated magma extending over a range of depths could contribute to the preservation of stable, density-stratified bodies of magma. (Authors' abstract)



ANDERSON, A.T., Jr., SKIRIUS, C., WILLIAMS, S.N., DRUITT, T., NEWMAN, S., and STOLPER, E., 1988, H_2O, CO_2, Cl and gas in Bishop Rhyolite (abst.): EOS, 1988. v.69, p.529. First author at Univ. of Chicago, Dept. of Geophys Sci., Chicago, IL 60637.

Glass inclusions in quartz phenocrysts from the plinian deposit (early, cool) and Mono Lobe ash-flow (late, hot) of the Bishop Tuff were analyzed for H_2O and CO_2 by IR spectroscopy and for Cl by electron microprobe.

Inclusions in plinian quartzes are typically large (≈300 μm), clear, round, and void-free. Most have 5.3-5.8 wt % H_2O, but a few are higher than 6 wt %. CO_2 contents range from <0.005 to 0.019 wt %. Cl is 0.07 wt %. Occasional gas bubbles comprise <0.4 vol % of the inclusions, suggesting a shrinkage origin.

Two types of inclusions are found in the Mono Lobe quartzes: (1) Most are clear, smaller than 200 μm, partly faceted and partly devitrified, and contain one or more shrinkage bubbles. H_2O is ≈4.3 wt %, CO_2 is 0.024-0.035 wt %, and Cl is 0.07 wt %. (2) "Hourglass" inclusions are rare, long (up to 1 mm) brown, slightly devitrified inclusions with a narrow (1-10 μm diameter) passageway to the crystal rim. Dissolved volatiles are ≈2.5 wt % H_2O, <0.01 wt CO_2, and 0.03 wt % Cl. Gas bubbles comprise 5-35 vol % and probably formed by effervescence during or just prior to eruption.

Excluding the hourglass inclusions, the measured H_2O contents are higher than Hildreth's (1977) estimates for the Bishop Tuff magma. Also, although inclusions in the plinian quartzes are richer in H_2O than those from the later-erupted ash-flow, the enrichment is less than Hildreth's estimate for the magma. The unexpected inverse correlation between H_2O and CO_2 for plinian vs. Mono Lobe inclusions may have developed in response to CO_2-rich bubbles rising through the magma chamber (from underlying basaltic magma?) and/or by progressive crystallization of vapor-saturated magma. (Authors' abstract)

See also Skirius & Anderson, this volume (E.R.)

ANDERSON, G.M., PASCAL, M.L. and RAO, Jilong, 1987, Aluminum speciation in metamorphic fluids, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 297-321. First author at Dept. Geol., Univ. Toronto, Toronto, Canada M5S 1A1.

In this article we present the results of some studies of the composition of an aqueous phase in equilibrium with various three-phase assemblages in the system K_2O-Al_2O_3-SiO_2. We interpret the results as indicating that the solutes are dominantly uncharged species, specifically alkali-alumina and alkali-alumina-silica species. (From the authors' text by E.R.)

ANDREW, A.S. and HEINRICH, C.A., 1986, Isotopic and fluid inclusion evidence for sources of mineralizing fluids at the Sundown tin prospect, SE Queensland: Res. Rev. 1985, CSIRO Div. Mineralogy & Geochem., Canberra, Australia, p. 68-69.

ANGEIRAS, A.G., 1988, Geology and metallogeny of the northeastern Brazil uranium-phosphorus province emphasizing the Itataia deposit: Ore Geol. Reviews, v. 3, p. 211-225. Author at Geólogo Antonio Gomes Angeiras, Rua Senador Vergueiro 81/1001, 22.230 Flamengo, Rio de Janeiro, Brazil.

The unconventional U deposit at Itataia is described in detail. Inclusions in the episyenites have NaCl contents that were probably very much higher than those described by Leroy 1971 (Les épisyenites non minéralises dans le massif de granite à deux micas de Saint-Sylvestre (Limousin, France), Ph.D. dissertation, Univ. Nancy), but initial T were similar. Inclusions in fourth stage minerals were saline and high in $CaCl_2$. Quotes unpublished data by Fuzikawa (1978) on inclusions in apatite (19.5-22.5 wt.% $CaCl_2$) and 4 wt.% in late quartz. (E.R.)

ANGELES, C.A., Jr., ANTIOQUIA, E.C. and COMIA, G.M., 1987, Geology and alteration-mineralization characteristics of the Nalesbitan gold deposit, Camarines Norte, Philippines: Proc., Gold '87 in the Philippine setting, Dec. 3-4, 1987, Manila, Vol. I: Manila, Philippine Inst. Mining, Metallurgy & Geol., p. 1/15-15/15.

The Nalesbitan Au deposit is situated ~190 aerial kms southeast of Manila. The area has been known to contain Au since the early 1930s and presently worked on by 10,000 Au panners. A tentative geologic resource of 5 millon tonnes averaging 1.6 g/t Au has been delimited at 0.5 g/t Au cut-off.

The area is underlain by a Pliocene volcano-sedimentary sequence of fluviatile to shallow-marine origin and intruded by cogenetic andesite dikes and domes. They form a part of the extensive Macogon Formation. The sequence was folded into a northwest-plunging syncline, which underwent pre- and post-mineral faulting along its axis. The pre-mineral structures controlled the emplacement of Au mineralization, whereas the post-mineral structures are sinistral gougy faults horizontally displacing mineralization by as much as 300 m.

Au mineralization is confined within several sub-vertical lenticular NW-trending silicified structures occurring within a 2-km strike length. The biggest structure is roughly 40-m wide x 2.3 km long, assuming an upward-flaring lense-shaped geometry. Hydrothermal breccia dikes and quartz-limonite (after pyrite) stockworks are common features of silicification and are the main loci of Au. Hypogene mineralization is typified by a high pyrite content and minor to trace amounts of Cu sulfides and sulfosalts, free Au and possibly Au-Ag tellurides. Supergene oxidation has completely transformed the sulfides to limonites and chalcocite-covellite except for some relict patches. Large (>1 mm) Au nuggets are commonly found in the soil overburden and limonite-filled structures.

The Nalesbitan Au deposit forms the lower portions of a high-level volcanic-hosted epithermal system of the acid-sulfide-type affiliation. The deposit had been stripped of an assumed quartz-alunitic cap and some of the Au-bearing silicified zones. Fluid inclusion studies suggest boiling of fluids and a T range of formation of 223-255°C, indicating paleodepths of about 300 to 460 m. (Authors' abstract)

ANTIPOV, A.F., 1988, Vacuum decrepitation in local prospecting for gold ore mineralization: Sov. Geol., 1988, no. 10, p. 109-112 (in Russian). Author at KazIMS, USSR.

Along with thermosonic decrepitation and Th studies of fluid inclusions, thermovacuum decrepitation was done for the rocks at a stockwork Au-sulfide-quartz ore deposit. The T interval of ore mineralization was established by examination of the thermovacuum decrepitation curves. The relation F = SH/T, where S, H, and T are the area, height, and average T of this peak, respectively, provides a measure of the intensity of ore formation. Also, the gas fraction sepg. in the T interval of productive mineralization (F_p) relative to the total amount of fluid in the samples is detg. by the intensity of ore genesis; it is an coefficient of sp. gas-sepn., given as $K_p = F_p 100 \Sigma F_i$. A graph of K_p vs. depth for the central part of the ore deposit was constructed as a prospecting tool, since it can be used to judge the ore-bearing potential of deep horizons and flanks of deposits. (C.A. 110: 138840v)

ARNASON, John and SELVERSTONE, Jane, 1988, Field, petrographic, and fluid inclusion evidence for oxidation during low-angle normal faulting, Tauern Window, eastern Alps (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A101. Authors at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138.

The western border of the Tauern Window is a low-angle normal fault that juxtaposes brittly deformed marbles and calcmica schists of the Australpine (AA) nappes against more ductily deformed graphitic schists (Upper Schieferhülle, USH) in the window. Within 10-20 m of the contact, the USH is strongly retrogressed from biotite schist to chlorite schist, pyrite is partially to completely altered to hematite, graphite disappears, and carbonate abundance (matrix and in veins with qtz) increases markedly. These features truncate lithologic layering and indicate that faulting was accompanied by significant oxidation (increase in $f(O_2)$ from $<10^{-31}$ to $> 10^{-28}$ bars) of the USH: pyrite alteration textures suggest that the oxidation occurred during deformation.

FI compositions indicate that at least two different fluids passed through the USH in the fault zone. The earlier inclusions occur in clusters and contain aqueous fluids with 5 wt % eq. NaCl and unaltered pyrite dxls. The later inclusions lie on healed fractures and contain H_2O-CO_2-NaCl-(CH_4?) fluids with no dxls and densities of <0.92 g/cc. Both inclusion types are found in concordant qtz pods but only the second type occurs in discordant qtz-carb veins. We suggest that the pyrite-bearing inclusions predate the oxidation, but that the later inclusions, which crosscut qtz-carb veins produced during oxidation of graphite, are syn- or post-oxidation. Qtz in the veins shows both ductile and cataclastic deformation features. Bulk Th combined with densities of the younger inclusions indicate minimum trapping T's of 300°C during decompression of the USH from ~5 to <2 kbar. Oxidation thus began during ductile shearing of the USH at depth, but may have continued during brittle deformation in the last stages of extensional unroofing of the window. (Authors' abstract)

ARTHUR, R.C. and BARNES, H.L., 1988, Precipitation of metal sulfides from geothermal brines in the Salton Sea area, southern California: An interpretation of results from field experiments (abst.): Terra cognita, v. 8, p. 184. Authors at College Earth & Min. Sci., Ore Deposits Res. Sec., The Pennsylvania State Univ., University Park, PA, USA.

Hydrothermal brines in the Salton Sea Geothermal Field (SSGF) often contain high concentrations of Pb, Zn, Cu and Fe, and low concentrations of dissolved sulfide. To determine the feasibility of simultaneous recovery of the dissolved metals during the production of electrical energy from reservoir fluids, and to simulate potential ore-forming processes under actual field conditions, we developed an experimental system for mixing fluids from a flowing well in the SSGF (Magmamax #1) with dilute aqueous solutions of Na_2S, and with H_2S gas. The experiments were conducted on site and at wellhead conditions (T ≅ 220°C, P ≅ 2.3 MPa, concurrent flow of Magmamax brine and steam).

The results indicate unexpectedly minor precipitation of the base metals. Only Pb and Zn concentrations are reduced, but by amounts rarely exceeding 10% of their initial concentrations and despite relative increases in dissolved sulfide by factors exceeding 100. The experimental results are not consistent with the high predicted yields for the metals based on the thermodynamics and kinetics of base-metal precipitation reactions in static aqueous systems.

The low yields of precipitated base metals may be understood by integrating the fluid dynamics of two-phase hydrothermal systems with the thermodynamics of precipitation reactions. Results show that the extent of base-metal precipitation is inversely related to the mass-flow proportions of steam/brine existing at the point of mixing. Interphase transfer of the added sulfide, from liquid to steam, sharply decreases the amount of aqueous sulfide available for base-metal precipitation, and effectively reduces yield even at very low steam/brine mass-flow ratios. (Authors' abstract)

ASKHABOV, A.M. and RAKIN, V.I., 1988, The role of the density gradient in the evolution of mineral-forming media (in connection with attempts to reconstruct the conditions of cavity-type mineral-formation based on inclusions in minerals), in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 49-56 (in Russian).

ATANASOV, V. and VASILEVA, M., 1987, Barite mineralization in Kremikovci deposit: God. VMGI-Sofia, 33, 1986-1987, no. 2, 1987, p. 67-79 (in Russian; English abstract).

Kremikovci deposit is characterized by the occurrence of hematite, siderite and limonite iron ores, zones of polymetallic mineralization and barite bodies. Two main genetic types of barite are distinguished: endogenic and exogenic. The endogenic barite is a typical hydrothermal mineral. Th of the gas-liquid inclusions in barite, formed in the end of the sulphide mineralization stage, is ~160-205°C. The exogenic barite was formed at the expense of dissolution and redeposition of the endogenic barite when the oxidation zone of the deposit was flooded by the waters of the Pliocene lake. The results of the chemical analyses show that the endogenic barite showed a typical feature - higher content of Sr (SrO up to 2.50 wt %). The supergenic barite differs in composition (SrO content up to 0.12 wt %), infrared spectra and thermoluminescence properties from the endogenic barite. (From the authors' summary)

AULSTEAD, K.L., SPENCER, R.J., and KROUSE, H.R., 1988, Fluid inclusion and isotopic evidence on dolomitization, Devonian of Western Canada: Geochim. Cosmo. Acta, v.52, p.1027-1035. First author at Dept. of Geo. and Geoph., The Univ. of Calgary, Calgary, Alberta, Canada T2N 1N4.

The Presqu'ile and Manetoe Facies are diagenetic features developed in Lower and Middle Devonian Formations of the Elk Point Basin (Presqu'ile) and the Mackenzie Shelf (Manetoe). Both facies contain coarsely crystalline dolomite and white sparry dolomite cement. Less extensive diagenetic phases, in order of paragenesis, include fluorite, anhydrite, barite, calcite, quartz, sphalerite and galena.

Conditions of dolomitization are outlined from core and outcrop examination, thin section and cathodoluminescent petrography, fluid inclusion analyses, and C and O isotopic data. Fluid inclusion and stable isotope analyses from dolomite are combined to determine the isotopic composition of the dolomitizing fluids. Chemical analyses of fluid inclusion waters are compared with formation water analyses to derive a proposed origin for the diagenetic fluids.

Dolomite formed from hot, high salinity fluids early in the diagenetic history of the basin. Limestone was dolomitized as a result of the same process that created white sparry dolomite cement in the Manetoe Facies. Remnants of the dolomitizing fluids are present as formation waters in some Devonian formations in Alberta.

Subsequent invasion of meteoric waters produced more dilute diagenetic fluids which resulted in the precipitation of calcite and quartz cement in the Manetoe Facies. These fluids are present in fluid inclusions and are responsible for the low ^{18}O content of the calcite cement. The T of calcite and quartz formation differ as a function of burial depth within the Manetoe Facies during the Mesozoic and Cenozoic, while the T of formation for dolomite does not. (Authors' abstract)

AURISICCHIO, C., DE VIVO, B., FREZZOTTI, M.L. and SCRIBANO, V., 1988a, Ultramafic nodules from Etna volcano (Sicily, Italy): Fluid inclusion and chemical studies (abst.): Kagoshima Int'l. Conf. on Volcanoes Abstracts, p. 258. First author at C.S. Miner. e Petrol. Form. IGNEE C.N.R., Ple. A. Moro 7, 00185 Rome, Italy.

Ultramafic nodules of deep source occur in the "Ancient Alkaline" lavas of the Etna volcano. A study of their fluid inclusions and mineral chemistry has been used to put constraints on their origin, P and T of formation. Fluid inclusions have been examined by microthermometric techniques using a heating-freezing stage; microprobe analyses have been performed on the nodule constituent minerals.

The host rocks are a series of small outcrops of hawaiitic composition placed above the tholeiitic basement. They have porphyritic texture with labradoritic plagioclase, Ca-rich augite, olivine and Ti-magnetite. The nodules of small size (max 3 cm^3) are dunites and wehrlites characterized by a Cr-diopsidic pyroxene. The dunites (20% of nodules) have "granular" or "tectonic" structure with olivine crystals (Fo 86) up to 1 cm, showing kink bands stressed along the normal to the growing direction. Round drops of Cr-spinel and Cr-diopside complete the assemblage. The wehrlites, with pecilitic[sic] structure, can be subdivided chiefly by color (emerald-green to dark-green) and Cr-content (Cr_2O_3 1.5-0.3) of the Cr-diopsidic megacrystals. The olivines ranging from Fo 86 to Fo 88, embedded in the clinopyroxene with lobate shapes, show kink bands, even if they do not matter [affect?] the host pyroxene. With decreasing Cr-content the olivine shows euhedral crystals without any distortion. The Cr-spinel gives variable Cr/Cr + Al ratios ranging from 0.2 to 0.5. Fluid inclusions containing essentially pure CO_2 and silicate glass have been found in clinopyroxene megacrystals, and represent the trapping of two immiscible fluids. Most of inclusions are S. The Th of vapor (V) and liquid (L) CO_2 ranges from +24.0°C to +31./1°C. 41% homogenize in the liquid phase (from +29.9°C to +31.0°C); 59% homogenize in the vapor phase (from +24.0°C to +30.9°C), yielding a CO_2 density that ranges from 0.23 to 0.61 g/cm^3. The frozen inclusions melt in a very narrow T range with Tm from -56.6°C to -57°C, suggesting essentially pure CO_2. If we assume a Tt of 1000°C for a pure CO_2 system, the Pt would be between 0.6 kbars and 2.6 kbars. Assuming that the inclusions were trapped in a P regime resulting solely from the hydrostatic P of the magma column, with a density of 2.7 g/cm^3, then the depth of trapping is between 2.4 and 10 km. (Authors' abstract) (See next item)

AURISICCHIO, C., DE VIVO, B., FREZZOTTI, M.L. and SCRIBANO, V., 1988b, Ultramafic nodules from Mount Etna (Sicily, Italy): Fluid inclusion and petrological studies: Kagoshima Int'l. Conf. on Volcanoes Proceedings, p. 91-94.

See previous item. (E.R.)

AURISICCHIO, C., DE VIVO, B., FREZZOTTI, M.L. and SCRIBANO, V., 1988c, Fluid inclusion geobarometry and petrological studies of nodules and xenocrysts in alkali lavas of Mt. Etna: CNR, Boll. Gr. Naz. Vulc., v. 4, p. 11-21 (in Italian; English abstract).

See previous items. (E.R.)

AUSBURN, K.E., 1988, Tertiary volcanic hosted epithermal Au-mineralization at the Hart mining district, Castle Mountains, NE San Bernadino County, California (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 140. Author at Vanderbilt Gold Corp., Las Vegas, NV 89102.

Au mineralization at Hart is confined to banded quartz veins and peripheral silicified hydrothermal breccias hosted by a 12.8 my rhyolite flow-dome complex that is part of an 18-12.8 my volcanic pile.

Ore stage vein mineralogy in quartz + adularia + pyrite + Au + calcite. Hematite, and alunite ± jarosite are post-mineralization vein minerals. Au occurs free, commonly as encrustations in pyrite. Au/Ag is typically >1.0. Argillic and propylitic alteration define a crude zonation around tabular centers of silicification.

Fluid inclusion studies of paragenetically constrained quartz vein material provide the following: (1) Mean ore stage fluid Th ≈ 190°-200°C. (2) Recognition of segregated zones of vapor and two-phase liquid dominant inclusions throughout ore stage quartz veins. (3) Recognition of distinct populations of NaCl eq. estimates within the range 0.18 to 10.86 wt% NaCl eq.; median ≈ 1.1 wt% NaCl eq.

Rb/Sr, δD and $\delta^{18}O$ isotopic studies of quartz veins, country rock units, and variously altered host rock produced the following: (1) Mineralized vein quartz + adularia Rb/Sr isochron age ≈ 12.4 my. (2) Mineralized vein quartz + adularia $^{87}Sr/^{86}Sr(o)$ from .7146 to .7141. (3) Variously altered rhyolite $^{87}Sr/^{86}Sr(o)$ from .7133 to .7158. (4) Fresh rhyolite $^{87}Sr/^{86}Sr(o)$ = .7110. (5)

Fresh bedded volcanics and sediments = .7079. (6) Fresh Precambrian basement $^{87}Sr/^{86}Sr(m)$ = .7866. (7) $\delta^{18}O(H_2O)$ form -3.5‰ to -8.0‰. (8) $\delta D(H_2O)$ from -86‰ to -103‰.

The following conclusions are offered: (1) Field relations show mineralization to be spatially and temporally related to rhyolite intrusion. (2) Fluid inclusions suggest incomplete mixing of dilute and more saline fluids, and a strong correlation between fluid boiling and deposition of Au. (3) Rb/Sr isotope data indicate that the hydrothermal fluids are a mixture of Tertiary magmatic and Precambrian metamorphic cation solutes. (4) Stable isotope data suggest a mixture of magmatic and meteoric water components. (Author's abstract)

AVERKIN, Yu.A., 1987, Component deposition from hydrothermal solutions on loss of CO_2: Geokhimiya, no. 11, p. 1580-1586 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 6, p. 65-72). Author at Inst. Geol. & Geophys., Siberian Div., Acad. Sci. of USSR, Novosibirsk, USSR.

The dynamics of iron-sulfide deposition from hydrothermal solution is examined at an alkali geochemical barrier, related to the loss of dissolved CO_2. There are sharp component-solubility gradients at the barrier, as well as differences in component concentration in solution and in the solid. The nonstationary stage of the process is characterized by mobility of the barrier and an increase of the values on the concentration profiles in time and space. Economic deposits are formed in volcanic systems only if there is a stationary position for the dissolved CO_2 loss. (Author's abstract)

AYERS, John and EGGLER, D.H., 1988, Partitioning of trace elements between silicate melts and H_2O-NaCl fluids at upper mantle pressures and temperatures (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 27. First author at Geosci. Dept., The Pennsylvania State Univ., University Park, PA 16802.

Partitioning of selected major and trace elements between silicate melts and supercritical hydrous fluids, containing 1.5 and 3.0 molal NaCl, has been determined at pressures of 15 and 20 kbar at 1250°C. Concentrations of trace elements -- K, Rb, Sr, La, Sm, Y, Tm, Ti, and Zr -- in anhydrous starting material ranged from 0.15 to 1.0 wt %. Solubility of melt in the fluid phase is approximately 51 wt % at 15 kb and 53 wt % at 20 kb, with no apparent dependence of NaCl concentration.

All major elements except Na display little fractionation between solute (anhydrous fluid) and melt[sic]. Solute is always more alkaline than coexisting melt. Fluid-melt distribution coefficients for trace elements ranged from 0.43 to 0.88, indicating only moderate fractionation of elements studied. More importantly, relative differences between groups of elements (alkalies, REE, HSFEs) are small, indicating little element/element fractionation involving fluids. In REE patterns, fluids are flat to slightly LREE-depleted. Lack of dependence of distribution coefficients on chloride concentration suggests that chloride complexing is unimportant at these conditions, except possibly for alkalies.

Results indicate that NaCl-bearing aqueous fluids caa be very effective metasomatic agents at mantle conditions. They are more effective than H_2O or H_2O-CO_2 fluids in terms of solute capacity. The chloride fluids will not, however, introduce a geochemical signature to a metasomatized mineral assemblage that is distinct from the signature of an aqueous fluid or a melt. (Authors' abstract)

AZBEL, I.Ya. and TOLSTIKHIN, I.N., 1988, Abundance of noble gases in MORB glasses: A key to the early history of the Earth (abst.): Chem. Geol., v. 70, p. 41. Authors at Geol. Inst., Kola Dept. of USSR Acad. Sci., Apatite 184200, USSR.

Isotope geochemistry of helium shows that degassing of the mantle is mainly related to partial melting and uplift of melts in rift and subduction zones, MORB glasses are the best representatives of the melts. The distribution of noble gases (high isotopic ratios for $^3He/^4He = 11.10^{-6}$, $^{40}Ar/^{36}Ar = 25,000$, $^{129}Xe/^{130}Xe = 7.20$; high $^{20}Ne/^{36}Ar$ and $^{130}Xe/^{36}Ar$ are compared atmosphere); and parent radioactive elements (K - 0.1% wt., K/U = 13,000) in fresh glasses are understood within the framework of a degassing model, which is based on partitioning of noble gases between melt and solid portion in the course of terrestrial magmatic processes and partial degassing of melts. Partition and solubility coefficients accentuate losses of argon, whereas He and Ne (due to high solubility and preservation in partially degassed melts) as well as Kr and Xe (due to high partition coefficients and preservation in solid portions) release mantle matter much slower than Ar. This is the reason of a huge "U-type" fractionation of the gases in MORB glasses, so that $(^{20}Ne/^{36}Ar)MORB/(^{20}Ne/^{36}Ar)Atm$ and $(^{130}Xe/^{136}Ar)MORB/(^{130}Xe/^{36}Ar)$ Atm sometimes attain 100.

The model envisages the following: an intensive convection in the upper mantle resulted in extraction of volatiles into the atmosphere in the early history of the Earth; later on continuous decrease of the rate of the convection which <u>yields</u> mantle magmatism and degassing; formation of the oceanic and continental crust from mantle melts; formation of the upper crust due to intra-crustal magmatic processes; recycling, degassing and contamination of materials of the crustal reservoirs.

To reconcile the observed and calculated noble gas abundances in MORB glasses a high rate of mass flux from the mantle interior to the crust (and corresponding reflux) must be provided in the past (10^{17} g.year^{-1}): 40 during the first 0.1 Ae of the Earth evolution, so that 75% of the ^{36}Ar in the upper mantle had been released; 15 during the following 0.15 Ae and 90% of Ar released; starting from 4.3 Ae ago the rate of recycling decrease from 5 to 0.5 and less than 0.5% of ^{36}Ar is still preserved in the upper mantle. (Authors' abstract)

BABANSKY, A.D., SOLOVOVA, I.P. and RYABCHIKOV, I.D., 1988, Conditions of generation of intermediate and silicic magmas based on thermobarogeochemical, experimental, and computer data, <u>in</u> Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 60-66 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 18. (E.R.)

BACON, C.R., NEWMAN, Sally and STOLPER, Edward, 1988, Preeruptive volatile content, climactic eruption of Mount Mazama, Crater Lake, Oregon (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A248. First author at USGS, 345 Middlefield Rd., Menlo Park, CA 94305.

Plagioclase phenocrysts in rhyodacite pumice of the climactic eruption of Mount Mazama contain rare ~ 100 μm glass inclusions. Inclusions in phenocrysts from two pumices from low in the plinian deposit were analyzed for H_2O and CO_2 by IR spectroscopy and for Cl and F by electron microprobe. Inclusions in all pumices examined from overlying ignimbrites are vesiculated or intersected by cracks. Uniform composition and mineralogy of climactic rhyodacite pumice suggest invariant preeruptive volatile content. Inclusions are compositionally similar to groundmass glass (anhydrous basis), and host plagioclase compositions are typical of phenocrysts in the pumice. Inclusions occur near the margins of patchy-zoned cores overgrown by oscillatory-zoned rims. Total water contents in early plinian samples are between 1.3 and 4.5 wt%; CO_2 is below the detection limit (50 ppm) in all inclusions measured. Four inclusions in three crystals have H_2O contents >4.2 wt%; we consider these to represent a preeruptive melt value of ~ 4.5 wt%. This value implies $P(H_2O)$ = 130 MPa, if vapor-saturated, or a minimum depth of 6 km. All lower H_2O measurements are for inclusions either adjacent to glass-decorated fractures or connected with groundmass by sub-μm capillaries (hourglass inclusions); we propose that these inclusions degassed during the eruption, as did inclusions in ignimbrite samples, owing to differential P between inclusions and melt brought about by unloading during the course of the eruption. Ratios of hydroxyl/molecular water for all inclusions indicate T far below magmatic, as do rhyolitic glass inclusions in quartz from the Bishop Tuff (A.T. Anderson et al., unpub.). Variation in halogen content generally is less than analytical precision, average values in the plinian inclusions are 400 ppm F, 1900 ppm Cl. Obsidian from the Cleetwood flow, emplaced shortly before the climactic eruption, has F and anhydrous composition similar to climactic pumice but only 0.1 wt% H_2O and 1100 ppm Cl owing to preferential loss on degassing. (Authors' abstract)

BAIN, J.G., 1988, A preliminary study of fluid inclusions in the shock metamorphosed sediments from the Haughton impact structure, Devon Island, Canada: BS thesis, Lakehead Univ., Thunder Bay, Ontario, Canada, 91 pp.

The Haughton impact structure is a well preserved meteorite crater that lies in the Paleozoic carbonate sediments of Devon Island in the Canadian Archepelago.

Monomict breccias, which are largely carbonate, show very few shock metamorphic effects. The gneisses show shock effects and have experienced P up to 25 GPa and T up to 300°C. Polymict breccias, containing thermally melted glass and shocked crystal fragments, display the highest degree of shock metamorphism, in the range of 25 to >55 GPa and 300 to more than 2000°C. These glass-bearing, polymict breccias are highly vesicular due the high P vaporization of water, silicate minerals and the decarbonation of carbonate sediments, mostly calcite, into CO_2 gas and CaO.

Small two-phase, liquid-vapor fluid inclusions are generally abundant in the normal glasses of the glass-bearing, polymict breccias. A thorough microthermometric study of these inclusions revealed that they are water-rich, lack CO_2, and have low salinities, in the range 0.3 to 3.37 eq. wt.% NaCl. Th are most frequent between 140 and 150°C, although the range spans 137 to 243°C.

The glasses in these polymict breccias are very fresh and unfractured. This suggests that the fluid in the inclusions did not come from a source outside of the host rock. The thermometric data indicate that the fluid inclusions formed shortly after the shock-produced melt had been released from high P.

Wet quartz and carbonate-rich sedimentary rocks that were shocked to more than 28 GPa, a common occurrence at Haughton, were melted and sometimes vaporized. Water from these rocks was dissolved, forming a superheated solution with the silicate melt. Upon passage of rarefraction waves a high-P, high-density, superheated water vapor exsolved from the superheated water-silicate melt. Much of this vapor was able to expand to atmospheric P, vesiculating the melt in the process. The high-P, high-density, superheated water vapors that did not have time to expand and reduce their internal P to that of the atmosphere before the melt quenched formed tiny, submicroscopic to 100 μm long vesicles. These tiny vesicles, filled with high-P, high-density vapor were the precursors to the two-phase, liquid-vapor fluid inclusions that were observed in this thesis. (From the author's abstract, by E.R.)

BAIN, J.G. and KISSIN, S.A., 1988, A preliminary study of fluid inclusions in shock-metamorphosed sediments at the Haughton impact structure, Devon Island, Canada (abst.): 51st Ann. Meeting of the Meteoritical Soc., Fayetteville, AR, July 18-22, 1988, Abstracts, p. D-7 (Lunar and Planetary Inst. Contrib. 665) (also Meteoritics, v. 23, p. 256). Authors at Dept. Geol., Lakehead Univ., Thunder Bay, Ont. P7B 5E1, Canada.

See previous item. (E.R.)

BAIN, J.H.C., WITHNALL, I.W., BLACK, L.P., ETMINAN, H., GOLDING, S.D. and SUN, S.S., 1988, Geologic, isotopic, and metallogenic aspects of gold mineralization in the Etheridge gold field, Georgetown region, Queensland (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 246-248. First author at Bureau of Min. Resources, Geol. & Geophys., Canberra, ACT.

The Au-quartz vein deposits of the Etheridge gold field formed from hot (200-350°C), moderately saline (about 10 wt% eq. NaCl) fluids containing SiO_2, H_2O, CO_2, S, and metals, that were focussed into extensive fracture systems during a major episode of granitoid emplacement about 400 Ma ago. The oxygen isotope data suggest that the ore fluid may have been highly modified meteoric water, or had a significant magmatic component. (From the authors' abstract)

BAKER, A.J., 1988, Stable isotope evidence for limited fluid infiltration of deep crustal rocks from the Ivrea Zone, Italy: Geology, v. 16, p. 492-495. Author at Grant Inst. Geol., West Mains Rd., Edinburgh EH9 3JW, Scotland.

Isotopic and petrologic studies of the Ivrea Zone, a segment of deep-crustal high-grade rocks, suggest that metamorphism did not involve the transfer of large quantities of CO_2 from mantle to crust. High-grade Ivrea Zone calcites may retain high $\delta^{18}O$ (up to 24‰ SMOW), indicating little interaction with externally derived fluid. Graphite isotopic compositions ($\delta^{13}C$ = -10‰ to -25‰ PDB) that do not vary with grade are attributed to mixing between carbonate carbon and biogenic noncarbonate carbon. Calcites from high-grade, carbonate-poor amphibolites have $\delta^{13}C$ of about 1‰ PDB and sedimentary, not infiltrative, origins. The general lack of carbon and oxygen isotopic homogenization suggests that fluid interactions may be explained in terms of fluid generated internally to the Ivrea Zone metasedimentary rocks. (Author's abstract)

BAKER, A.J. and FALLICK, A.E., 1988, Evidence of CO_2 infiltration of granulite facies rocks from Lofoten-Vesteralen, Norway: Chem. Geol., v. 71, p. 366.

The carbon and oxygen isotope signatures of marbles have been measured from across the amphibolite-granulite transition. Amphibolite facies marbles retain close to premetamorphic carbon and oxygen isotopic signatures ($\delta^{13}C \sim +10‰$, $\delta^{18}O \sim +26‰$). Granulite facies marbles and the margins of marbles near the amphibolite-granulite transition show large correlated shifts to lighter carbon and oxygen (to $\delta^{13}C \sim -7‰$, $\delta^{18}O \sim +10‰$). These shifts are attributed to interaction with a carbon and oxygen-bearing fluid, presumed to be CO_2-rich on account of the large number of CO_2-rich fluid inclusions present. The high CO_2-rock ratios experienced by marbles is consistent with the movement of large quantities of CO_2 through the crust. The lower limit to the carbon isotopic composition of marbles of $\delta^{13}C$ = -7‰ and the proximity of the most ^{18}O and ^{13}C depleted marbles to intrusives with large mantle components suggests a mantle origin for this CO_2. However a mixed crustal origin, from organic carbon and carbonate derived carbon is also possible. The study suggests that the CO_2 flushing model for granulite formation is sometimes valid. It may be that mantle CO_2 degassing rates were higher in the Precambrian and that therefore carbonic metamorphism is commoner in older granulite facies rocks, such as those in the Lofoten-Vesteralen province. (Authors' abstract)

BAKER, E.M. and ANDREW, A.S., 1988, Processes associated with gold mineralization within the Kidston breccia pipe, North Queensland (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 102-109. First author at Eastern Caribbean Mining Dev. Ltd., San Jose, Costa Rica.

Four types of inclusions were recognized: type S contain ≤5 dms (KCl, NaCl, Fe ± K chlorides), salinities of 40-50 wt.%, with NaCl/KCl of 1 to 2, Th L-V 100-200°C, and Th = 350-600°C; types L and V have Th L or Th V at 200-500°C; and type C (CO_2) homogenize in L or V. Types S, L and V are coeval; P estimates >800 bars from Tm dms ≤600-°C.

The original fluid was type S; later boiling formed types V and L. Au deposition (still later) was at 250-350°C. (E.R.)

BAKHANOVA, E.V., 1988, The use of thermobarogeochemical data during the search for and assessment of gold mineralization, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 131-136 (in Russian).

BALLHAUS, C.G., 1988, Potholes of the Merensky reef at Brakspruit shaft, Rustenburg platinum mines: Primary disturbances in the magmatic stratigraphy: Econ. Geol., v. 83, p. 1140-1158. Author at Inst. Mineal. & Petrol., Mining Univ., A-8700 Leoben, Austria.

Potholes are traditionally considered to be resorption pits due to the influx of a new hot primitive magma at the Merensky reef level or to represent scars of a late magmatic fumarole activity. The present study suggests that cumulate resorption played a minor role only. Potholes are sites of nondeposition, where the missing rock units did not crystallize. They formed where locally high concentrations of dissolved C-H-O-S volatiles lowered the liquidus T of the magma and suppressed the crystallization of cumulus plagioclase. Potholes seem to be concentrated above anticlines of the metasedimentary basement rocks in the foot wall of the Bushveld Complex. Volatiles derived by pyrometamorphism were focused upward into the overlying melt above such topographic highs and were accumulated at the level of Merensky reef. (From the author's abstract)

Fluid inclusion evidence suggests that the major volatile species were CH_4, H_2O and H_2S, as well as some HCl and very minor amounts of CO_2. Where a separate fluid exsolved from the melt, it was obviously saturated with carbon, in order to achieve the extraordinarily high concentrations of graphite in some potholes. (From the author's text)

BANK, F.H., BANK, H., GÜBELIN, E. and HENN, U., 1988, Alexandrite from a new occurrence near Hematita in Minas Gerais, Brazil: Z. Dt. Gemmol. Ges., v. 36, no. 3/4, p. 121-131 (in German; English abstract). First author at Idar-Oberstein and Heidelberg, West Germany.

Liquid and two-phase inclusions are mentioned. (E.R.)

BANK, H., GÜBELIN, E., HARDING, R.R., HENN, U., SCARRATT, K. and SCHMETZER, K., 1988, An unusual ruby from Nepal: J. Gemm., v. 21, p. 222-226. First author at Deutsche Stiftung Edelsteinforschung, Idar-Oberstein, West Germany.

A high quality ruby from Nepal is described. The stone, weighing 1.288 ct, revealed extraordinary growth structures connected with color zoning as well as mineral inclusions (phlogopite), feathers consisting of two- and most probably three-phase inclusions and ultra-fine fluid films, as diagnostic characteristics. (Authors' abstract)

BANK, H., GÜBELIN, E., HENN, U. and MALLEY, J., 1988, Alexandrite: Natural or synthetic?: Z. Dt. Gemmol. Ges., v. 37, p. 49-52 (in German; English abstract).

This paper describes [fluid and solid] inclusion investigations and analyses of an alexandrite, which was found to be synthetic by a European institute. The results of this work definitely prove the stone to be of natural origin. (Authors' abstract)

BANNIKOVA, L.A., GRICHUK, D.V. and RYZHENKO, B.N. 1987, Calculation of chemical and isotopic equilibria in the systems C-H-O and their application to a study of redox reactions in hydrothermal systems: Geokhimiya, 1987, no. 3, p. 416-429 (in Russian; English abstract).

Using computer simulation a calculation of possible equilibrium concentrations of CO_2, CH_4 and CO generated as a result of reactions among carbon dioxide, methane and water in the closed system at 200, 300, 500 and 650°C has been made. Using values of free energies of formation of isotopic forms of the compounds permits calculation, within the outlines of the united thermodynamic model, of the isotopic characteristics of carbon compounds also. Conditions of formation and possible values of $\delta^{13}C$ for this system have been considered. A comparison of the characteristics obtained with the appropriate values for the systems, which state is determined by redox reactions between the carbon-bearing components and outer (in relation to the system C-H-O) oxidizers and reductants, in a number of cases permits determination of the character of potential-controlling reaction. Examples of using of the proposed method for interpretation of isotopic and chemical data on the natural objects have been considered. (Authors' abstract)

BARGAR, K.E., 1987, Fluid inclusion data for drill hole PLTG-1, Platanares geothermal area, Honduras: Geother. Resources Council, Transactions, v. 11, p. 225-229. Author at U.S. Geol. Survey, Menlo Park, CA.

Liquid-rich S fluid inclusions in barite and calcite from drill hole PLTG-1 in the Platanares geothermal area, Honduras, have Th that range as much as several tens of degrees Celsius higher than the warmest reported T for the drill hole. Many of the barite Th measurements plot above a reference-surface boiling-point curve; however, absence of evidence for boiling in the fluid inclusions indicates that at the time the minerals formed, the ground surface must have been several tens of meters higher than at present and underwent stream erosion to the present elevation. Tm values for drill hole PLTG-1 fluid inclusions suggest that much of the barite and calcite precipitated from fluids of significantly greater salinity than present Platanares hot spring water. (Author's abstract)

BARGAR, K.E. and FOURNIER, R.O., 1988, Effects of glacial ice on subsurface temperatures of hydrothermal systems in Yellowstone National Park, Wyoming: Fluid-inclusion evidence: Geology, v. 16, p. 1077-1080. Authors at U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94025.

Hydrothermal quartz and fluorite crystals containing liquid-rich fluid inclusions (coexisting vapor-rich fluid inclusions were not observed) were found in drill cores from eight relatively shallow research holes drilled by the U.S.G.S. in and near major geyser basins of Yellowstone National Park. Th for mostly S fluid inclusions show variations in T that have occurred at given depths since precipitation of the host minerals. Within major hydrothermal upflow zones, Th values all were found to be equal to or higher (commonly 20-50°C and up to 155°C higher) than present T at the depths sampled. During periods when thick glacial ice covered the Yellowstone National Park region, pore-fluid P in the underlying rock were increased in proportion to the weight of the overlying column of ice. Accordingly, theoretical reference boiling-point curves that reflect the maximum T attainable in a hot-water geothermal system at a given depth were elevated, and T within zones of major hydrothermal upflow (drill holes Y-2, Y-3, Y-6, Y-11, Y-13, and upper part of Y-5) increased. The thicknesses of ice required to elevate boiling-point curves sufficiently to account for the observed Th values are within the ranges estimated by glacial geologic studies. At the margins of major hydrothermal upflow zones (drill holes Y-4 and Y-9), Th values at given depths range from 57°C lower to about the same as the current T measurements because of a previous decrease in the rate of discharge of warm water and/or an increase in the rate of recharge of cold water into the hydrothermal system. (Authors' abstract)

BARGAR, K.E. and FOURNIER, R.O., 1988b Fluid-inclusion evidence for previous higher temperatures in the Miravalles geothermal field, Costa Rica: Geothermics, v. 17, no. 5/6, p. 681-693. Authors at U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94025, USA.

Heating and freezing data were obtained for liquid-rich S fluid inclusions in magmatic quartz, hydrothermal calcite and hydrothermal quartz crystals from 19 sampled depths in eight production drill holes (PGM-1, 2, 3, 5, 10, 11, 12 and 15) of the Miravalles geothermal field in northwestern Costa Rica. Th for 386 fluid inclusions range from near the present measured T to as much as 70°C higher than the maximum measured well T of ~240°C. Melting-temperature measurements [Tm ice?] for 76 fluid inclusions suggest a calculated salinity range of ~0.2-1.9 wt% NaCl eq. Calculated salinities as high as 3.1-4.0 wt% NaCl eq. for 20 fluid inclusions from the lower part of drill hole PGM-15 (the deepest drill hole) indicate that higher salinity water probably was present in the deeper part of the Miravalles geothermal field at the time these fluid inclusions were formed. (Authors' abstract)

BARKER, C.E., 1988, Fluid inclusions in the Pleistocene Miami Limestone, southeastern Florida: Potentially misleading evidence of vadose diagenesis (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A119. Author at U.S. Geol. Survey, Box 25046, MS 971, Denver, CO 80225.

Vadose cements in the upper Pleistocene Miami Limestone contain regions with large (up to 280 μm), two-phase aqueous FI. These inclusons, which have similar vapor to liquid ratios, are judged to be primary. Small, obscure single-phase aqueous inclusions also occur throughout the vadose cement. The two-phase inclusions homogenize to a liquid phase in a range between 75°C and 130°C (mean = 100°C). The single-phase inclusions [imply] a low-T origin (less than 60°C) and contradict the higher T origin implied by the two-phase inclusions.

The $\delta^{18}O$ composition of these cements (-4 to -5.5‰, PDB) and the fresh water in the fluid inclusions (final melting T of ice between -0.3° and 0.0°C) suggest precipitation from low-T meteoric water. Low T meteoric diagenesis is consistent with the burial history and cement petrography.

The higher T indicated by the two-phase inclusions are apparently caused by the trapping of air and water at low T. This type of inclusion gives a spurious Th.

Proper interpretation of the diagenetic history requires consideration of the entire fluid inclusion population and the realization that conspicuous two-phase inclusions can be easily overemphasized. (Author's abstract)

BARKER, C.E., and HALLEY, R.B., 1988, Fluid inclusions in vadose cement with consistent vapor to liquid ratios, Pleistocene Miami Limestone, southeastern Florida: Geochem. Cosmo. Acta, v.52, p.1019-1025. First author at U.S. Geol. Survey, Box 25046, MS 971, Denver, CO 80225, USA.

Vadose cements in the late Pleistocene Miami Limestone contain regions with two-phase aqueous fluid inclusions that have consistent vapor to liquid (V-L) ratios. When heated, these seemingly P inclusions have Th(L) between 75°C and 130°C (mean = 100°C) and have Tm between -0.3° and 0.0°C. The original distribution of Th was broadened during measurements because of fluid inclusion reequilibation. The narrow range of Th in these fluid inclusions suggest unusually consistent V-L ratios. They occur with small, obscure, single phase liquid-filled inclusions, which infer a low T origin (less than 60°C), and contradict the higher T origin implied by the two phase inclusions.

The diagenetic environment producing these seemingly P fluid inclusions can be inferred from the origin of the host calcite enclosing them. The $\delta^{18}O$ composition of these cements (-4 to -5.5‰, PDB) and the fresh water in the fluid inclusions are consistent with precipitation from low-T meteoric water. The carbon-isotope composition of the vadose cements that contain only rare two-phase fluid inclusions are comparable to the host rock matrix ($\delta^{13}C$ between 0 and +4‰, PDB). Cements that contain common two-phase fluid-inclusions have a distinctly lighter carbon isotopic composition of -3 to -5‰. The carbon isotope composition of cements that contain common two-phase inclusions are about 6‰ lighter than those of other vadose cements; models of early meteoric diagenesis indicate that this is the result of precipitation from water that has been influenced by soil gas CO_2.

Our hypothesis is that the P fluid inclusions, those with consistent V-L ratios and the single-phase liquid inclusions, form at near-surface T (25°C) and pressure when consistent proportions of soil gas and meteoric water perculating through the vadose zone are trapped within elongate vacuoles.

This study corroborates that Th measurements on two phase inclusions in vadose cements can be misleading evidence of thermal diagenesis, even if the measurements are well grouped. (Authors' abstract)

BARNABY, R.J. and BODNAR, R.J., 1988, High-salinity overpressured fluids associated with MVT mineralization, Shady Dolomite (Cambrian), Virginia (abst.): AAPG Bull., v. 72, p. 157-158. Authors at Virginia Tech., Blacksburg, VA.

In Virginia, MVT Pb-Zn deposits are present in platform margin carbonates of the Lower Cambrian Shady Dolomite. Ore deposition occurred during the 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 PS fluid inclusions (up to 30-40 μm) in authigenic quartz contain a liquid and vapor phase and halite dms. The L-V (L) occurred between 110° and 140°C; total homogenization (by halite disappearance) occurred at 176°-225°C. Salinities, based on Tm (halite), are estimated to be 31-33 wt. % NaCl eq., assuming a pure $NaCl-H_2O$ system. However, Te (-26° to -25°C) indicates the presence of divalent cations (Ca^{2+} and/or Mg^{2+}).

Minimum trapping P, estimated from the intersections of the inclusion isochores with the liquidus curves corresonding to inclusion salinities, range from 430 to 1,370 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 inclusions, therefore, were overpressured, which is consistent with other evidence indicating the former presence of overpressured fluids.

A mininum depth of formation calculated from the lowest T of total homogenization (176°C) using a geothermal gradient of 35°C/km is about 4-5 km, consistent with the estimated 5-km thick overlying Paleozoic section.

Maximum burial depth estimated by projecting the isochores delimiting the P-T conditions of fluid inclusion formation up to a maximum T of 250°C is about 6-7 km. This additional P could be generated by tectonic thickening during thrusting. (Authors' abstract)

BARNES, Ivan, EVANS, W.C. and WHITE, L.D., 1988, The role of mantle CO_2 in volcanism: Applied Geochem., v. 3, p. 281-285. First author at U.S. Geol. Survey, 847 NE 19th St., Suite 300, Portland, OR 97232, USA.

Carbon dioxide is the propellant gas in volcanic eruptions and is also found in mantle xenoliths. It is speculated that CO_2 occurs as a free gas phase in the mantle because there is no reason to expect CO_2 to be so universally associated with volcanic rocks unless the CO_2 comes from the same source as the volcanic rocks and their xenoliths. If correct, the presence of a free gas in the mantle would lead to physical instability, with excess gas P providing the cause of both buoyancy of volcanic melts and seismicity in volcanic regions. Convection in the mantle and episodic volcanic eruptions are likely necessary consequences. This suggestion has considerable implications for those responsible for providing warnings of impending disasters resulting from volcanic eruptions and earthquakes in volcanic regions. (Authors' abstract)

BARNES, S.J. and CAMPBELL, I.H., 1988, Role of late magmatic fluids in Merensky-type platinum deposits: A discussion: Geology, v. 16, p. 488-491. First author at Commonwealth Sci. & Industrial Res. Org., Div. Exploration Geosci. Wembley, Western Australia 6014, Australia.

A number of features of platinum group element (PGE)-rich layers in layered intrusions provide evidence for the involvement of late magmatic fluids. The presence of pegmatitic textures, intergrowth of sulfides with intercumulus volatile-rich phases, high Cl content in volatile-bearing phases, and association with graphite and fluid inclusions have been taken by some authors as evidence for postcumulus transport and deposition of PGE by a fluid phase of late magmatic derivation. We argue that these apparently hydrothermal features are the result of postcumulus processes superimposed on layers whose extensive, uniform PGE concentrations were formed by magmatic cumulus processes.

The association with pegmatites and volatiles arises from the relatively low solidus T of orthocumulate layers, which cause these layers to act as traps for fluids migrating through the crystal pile. These fluids are mostly derived by vapor exsolution from fractionated intercumulus melt and are consequently enriched in Cl. Redissolution of these fluids into vapor-undersaturated trapped liquid in orthocumulate layers causes recrystallization and formation of gabbro pegmatites.

Immiscible sulfide-oxide liquid solidifies at near-solidus T in the interstitial pore space between early-crystallizing silicate minerals, and it is forced into areas occupied by late-crystallizing Cl-bearing silicates. This accounts for intergrowths of Cu and PGE-rich sulfides with amphiboles and micas, a ubiquitous feature of sulfide-bearing gabbros.

Further exsolution of a vapor phase during late stages of crystallization caused deuteric alteration, formation of fluid inclusions, and possible local redistribution of sulfides and PGE. Cooling of this vapor phase may lead to precipitation of graphite at or below the orthocumulate solidus. Graphite deposition may be catalyzed by sulfides and PGE. (Authors' abstract)

BARRES, O., BURNEAU, A., DUBESSY, J., PAGEL, M. and PIRONON, J., 1988, Application of micro-FTIR spectroscopy to individual fluid inclusion analysis (abst.): Chem. Geol., v. 70, p. 178. Authors at Lab. Spectrométrie de

Vibrations, Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France.

Infrared spectra of fluid inclusions are obtained with a Fourier Transform Infrared (FTIR) microspectrometer. Interferograms are recorded in the transmission mode. The quality of spectra is good for fluid inclusions with diameter larger than 20 µm, the spectral resolution being 4 cm^{-1} and the recording time 200 s by accumulation of 400 scans. The limit of 200 µm is reached in the same time with a worse spectral resolution. IR spectra are usually only suitable above 2000 cm^{-1} because of the absorption of most of the inclusion-bearing host minerals (i.e., quartz, feldspar ...) the thickness of which should never exceed 1 mm. This fact limits their interpretation especially when the inclusion composition is complex. However complementary information can be obtained in the 4600-4000 cm^{-1} range for hydrocarbon inclusions with a thickness larger than some tens of micrometers. Thus it is necesary to use a detector which is as sensitive as possible towards high frequencies. Methane, carbon dioxide, liquid water, aromatic ester and linear or branched alkanes are identified in the samples and the mean ratio of alkanes CH_2/CH_3 can also be estimated. For nonfluorescent fluid inclusions, comparison of performances of Raman and infrared microspectrometries can be made to determine the CO_2/CH_4 ratio. With the classical dispersive infrared spectrometers, a 4 mm^2 section is analyzed. The use of a microscope allows to get the spectrum of individual fluid inclusion and to characterize heterogeneities. (Authors' abstract)

BARRETT, T.J. and ANDERSON, G.M., 1988, The solubility of sphalerite and galena in 1-5 m NaCl solutions to 300°C: Geochimica Cosmo. Acta, v. 52, p. 813-820.

BARRETT, T.J., ANDERSON, G.M. and LUGOWSKI, J., 1988, The solubility of hydrogen sulphide in 0-5 m NaCl solutions at 25°-95°C and one atmosphere: Geochimica Cosmo. Acta, v. 52, p. 807-811.

BARTON, J.M., Jr., VAN REENEN, D.D., SMIT, C.A., BOHLENDER, F. and CORNELL, D., 1988, Charnockitization in the southern marginal zone of the Limpopo orogen, southern Africa (abst.): Chem. Geol., v. 70, p. 140. Authors at Dept. Geol., Rand Afrikaans Univ., P.O. Box 524, Johannesburg 2100, South Africa.

The transformation of biotite-bearing tonalitic and trondhjemitic grey gneisses into massive black charnockite may be observed within the southern marginal zone of the approximately 2700-2650 Ma Limpopo orogen of southern Africa. Here this transformation involves open system recrystallization over millimeter distances along metasomatic fronts. During charnockitization, hypersthene formed at the expense of biotite and hornblende and plagioclase became more calcic. The black color of the charnockites is believed to result from CO_2-rich fluid inclusions in plagioclase. (From the authors' abstract by H.E.B.)

BASTOUL, A., CATHELINEAU, M. and CUNEY, M. 1988, Metamorphic and hydrothermal fluids associated with Les Bondons uranium deposit: P-T-X characteristics (abst.): 12th Reunion des Sci. de la Terre, 27-29 April, 1988, Abstracts, p. 10 (in French). First author at Dept. Géol., Fac. des Sci., BP S15, Univ. Cady Ayad, Marrakesh, Morocco.

Three metallogenic stages have been recognized in this region: 1. an early metamorphic stage associated with brannerite; 2. a low-T hydrothermal stage with pitchblende and sulfides; 3. stages of supergene reworking. The fluids have been studied in mineralized zones, metamorphic quartz, granite and late veins associated with the pre-Lias paleosurface. Four main types of fluids have been identified: 1. CO_2-N_2 dominant ± CH_4; 2. CO_2-CH_4-H_2O with a

group of vapor-dominated inclusions in which Th is near 400°C, and another group of liquid-dominated inclusions (200°C < Th < 300°C); 3. aqueous fluids of low salinity (100°C < Th < 300°C); 4. aqueous fluids with Th < 100°C. In a N_2-CH_4-CO_2 diagram, the compositions of inclusions in quartz from several specimens define a trend which can be interpreted as the dilution of a reducing fluid (N_2 + CH_4) by an oxidizing fluid (CO_2 + H_2O). Such a mechanism may be responsible for the synmetamorphic brannerite. The presence of a redox gradient between the granite, the carbonaceous schists and other more oxidized metamorphic units is fundamental to the mobilization and concentration of U during metamorphic and hydrothermal processes. (Authors' abstract, translated by C.J. Eastoe)

BAUMGARTNER, L.P. and EUGSTER, H.P., 1988, Experimental determination of corundum solubility and Al-speciation in supercritical H_2O-HCl solutions (abst.): Geol. Soc. Amer. Abstracts with Programs., v. 20, p. A191.

BAZRAFSHAN, Khosrow and NORMAN, D.I., 1988, Fluid inclusion study of Hermosa mining district (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 141. Authors at Geosci. Dept., New Mexico Tech., Socorro, NM 87801.

A district-wide (30 km^2) fluid inclusion and mineralization in the Hermosa district was investigated by 450 samples and a total of 7500 fluid inclusion analyses. The results of the thermometric analysis show that the deposits in the district are shallow seated, partially boiling, epithermal deposits. A mineralization T of 250° to 290°C and salinity range of 0 to 9 eq. wt% NaCl have been determined.

Analysis of the data reveals a T zonation in the district and T distribution maps of the region were developed. These maps indicate a higher T zone in the northern part of the district. Three bull's eyes show T variations in the district. There is a general correlation between mineralogy and T zonation. Au occurrences are associated with the higher T zones, and Ag and base metal occurrences are associated with medium to lower T zones. The highest amount of quartz occurs in the hottest zones, and talc and calcite gangues are associated with medium T while calcite and barite are associated with lower T. This T and mineral zonation is consistent with fossil and present day hydrothermal systems.

It seems the T zonation is controlled by regional and local faults and intrusive bodies. The hottest one is associated with major regional faults and their intersections and rhyolite domes in the region. Medium and lower T zones are also related to major regional and local faults and their intersections in the region. It is concluded that major hydrothermal cells were active during mid-Tertiary time, and their hot fluids penetrated major regional and local faults and fractures upward, and caused the mineralization in the district. Fluid inclusion data can be used to map the paleohydrothermal cells and determine centers of Au and Ag-base metal mineral deposits. (Authors' abstract)

BEATY, D.W., CUNNINGHAM, C.G., NAESER, C.W. and LANDIS, G.P., 1988, Genetic model for the carbonate-hosted Pb-Zn-Cu-Ag-Au manto-chimney deposits of the Gilman, Colorado district based on fluid inclusion, stable isotope, geologic, and fission-track time-temperature studies (extended abst.): U.S. Geol. Survey Circular 1035, p. 4.

See next item. (E.R.)

BEATY, D.W., NAESER, C.W., CUNNINGHAM, C.G. and LANDIS, G.P., 1988, Genetic model for the Gilman district (Colo.), based on fluid inclusion, stable isotope, geologic, and fission-trace time/temperature studies (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A38. First author at

Chevron Oil Field Res. Co., P.O. Box 446, La Habra, CA 90633.

Multidisciplinary research has established a comprehensive genetic model for the Zn-Pb-Ag-Cu-Au ores of the Gilman district. The manto/chimney ore complex, which is mostly hosted in the Mississippian Leadville Dolomite, was derived from mid-Tertiary, high-T, igneous-related, hydrothermal fluids. Age of Mineralization: Hydrothermal apatite in the main ore body has a fission-track age of 34.5 ± 2.6 Ma, and a large paleothermal anomaly of the same age surrounds the district. Source of Ore Components: Sulfur isotope data indicate a homogeneous sulfur source for the main ore body, with a composition (bulk $\delta^{34}S = +1.6$) indicating an igneous provenance. The lead isotopic ratios in the ore are indistinguishable from those of Tertiary igneous rocks throughout Colorado. Transport Mechanism: The components of the main ore body were transported by an aqueous fluid with $\delta^{18}O = +4$ to +8 and $\delta D = -55$ to -75 permil (inferred magmatic water). This fluid had a mean salinity of about 5 wt. % eq. NaCl (range = 1.5 to 9.4). Temperature of Formation: The T of sulfide deposition in the region of the chimney deposits is estimated to be 390°-410°C based on both FI and sulfur isotope fractionation data. Lower T have been determined for the No. 1 Manto (300°-375°C), for veins in the Cambrian Sawatch Quartzite (230°-370°C), for late vug apatite (309°C), and for veins cutting Precambrian rock below the chimneys (174°-306°C). Direction of Fluid Movement: The distribution of mineralization and alteration, and thermal anomalies around the main ore body suggest updip fluid transport within the Sawatch Quartzite, followed by up-section flow through the chimneys to the Leadville Dolomite, and finally up-dip flow within the Leadville (controlled by structure, permeability contrast, and paleo-karst features). Several small, paragenetically early, partially preserved, Ag-Pb-Zn deposits at Gilman are similar in many ways to those at the Mt. Sherman mine to the east of the Leadville district. (Authors' abstract)

BEATY, D.W., TAYLOR, H.P., Jr. and COAD, P.R., 1988, An oxygen isotope study of the Kidd Creek, Ontario, volcanogenic massive sulfide deposit: Evidence for a high ^{18}O ore fluid: Econ. Geol., v. 83, no. 1, p. 1-17. First author at 13939 W. Cedar Place, Golden, CO 80401.

Preliminary inclusion data from E.T.C. Spooner (p. 12) indicates T ~300°C. (E.R.)

BEIN, Amos and DUTTON, A.R., 1988, Distribution of Na-Cl and Ca-Cl brines in the Southern Great Plains (U.S.A.) ground-water flow system and displacement of connate water (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A363. First author at Israel Geol. Survey, 30 Malkhe Ysrael St., Jerusalem, Israel 95501

Major geohydrologic units beneath the Southern Great Plains of eastern New Mexico and the Texas Panhandle include 1) an upper, fresh-water aquifer, 2) a middle, brine-bearing confining system in Upper Permian evaporites, shale, and carbonates, and 3) a deep, brine-bearing aquifer system in Lower Permian, Pennsylvanian, and pre-Pennsylvanian rocks. Mapping of brine chemistry analyses revealed the 3-dimensional distribution of Na-Cl and Ca-Cl brines in the deep-basin aquifer and evaporite confining systems. Na-Cl brines are $\delta^{18}O$ depleted and dominate in the western part of the deep aquifer system as well as in salt-dissolution zones at the lateral and upper margins of the evaporite confining system. Ca-Cl brines are $\delta^{18}O$ enriched and dominate in the central and eastern parts of the deep aquifer system and in most of the evaporite confining system.

One explanation of brine distribution is that meteoric water recharges the deep-basin aquifer in clastic rocks at the western side of the Southern Great Plains regional flow system and evolves to a Na-Cl brine by dissolving halite and anhydrite at the western margin of the evaporite confining system. The Ca-Cl brine possibly is a connate water that evolved by fluid mixing and diagenetic reactions from Permian seawater that was evaporatively concentrated in halite- and gypsum-precipitating lagoons. Ca-Cl brine composition was little modified until the late Cenozoic, when Neogene basin uplift established a regional potentiometric gradient across the Southern Great Plains. Influx of meteoric water displaced connate Ca-Cl brine from the western part of the deep basin aquifer but not from the thick evaporite confining system.

The Na-Cl and Ca-Cl brines are intercalated within the deep aquifer system, reflecting stratigraphic differences in transmissivity and hydrologic continuity between near-surface recharge areas and the deep subsurface. Breadth of the mixing zone between fluid masses is greater in thick, transmissive sandstone deposits flanking basement uplifts than in carbonate and shale deposits in the basin interiors. Assuming the second explanation is valid, position and breadth of the mixing zone between Na-Cl and Ca-Cl brines are used to calculate basin-average ground-water velocity and dispersivity distributions. (Authors' abstract)

BELEVTSEV, Ya.N. and ZHUKOV, F.I., 1988, The polygenic nature of pitchblende-carbonate veins in the aureoles of granitoid intrusions in the Variscan fold districts of Europe: Geol. Rudnykh Mestor., v. 30, no. 4, p. 48-57 (in Russian; translated in Int'l. Geol. Review, v. 30, p. 793-802). Authors at Inst. Geochem. & Physics of Min. of Acad. Sci. Ukrainian SSR, Kiev.

Isotopic studies (Pb, S, C, H, and D) indicate the complex polygenic nature of the East European uranium deposits. (Authors' abstract)

Includes five analyses of $\delta^{13}C(CO_2)$, $\delta D(H_2O)$ and $\delta^{18}O(H_2O)$ from fluid inclusions in quartz. (E.R.)

BELKIN, H.E., 1988, Fluid inclusion and mineralogic studies of palladium-platinum anomaly zone in the Reeser's Summit diabase, Pennsylvania: Evidence for hydrothermal transport (extended abst.): U.S. Geol. Survey Circular 1035, p. 4-6.

The York Haven diabase sheet (Early Jurassic) crops out near the northern margin of the Gettysburg basin (near Harrisburg, PA). Gottfried and Froelich (USGS Bull. 1776, 1988) have defined a PGE anomaly associated with a ferrogabbro zone at Reeser's Summit, PA. The Reeser's Summit exposure consists of a 500 m section of a high-Ti (1.1 wt%) quartz-normative tholeiitic magma of the York Haven type (Gottfried and Froelich, 1988). The chilled margins contain typical PGE abundances (Pd = 10 ppb, Pt = 10 ppb), whereas the greatest anomaly in the 90 m thick ferrogabbro zone (FeO tot. $\leq$18 wt%) contains Pd = 165 ppb, and Pt = 21 ppb. Associated with this zone are anomalously high contents of Au ($\leq$54 ppb), Te ($\leq$20 ppb), and Cl $\leq$0.44 wt%) (Gottfried et al., Goldschmidt Conf. Program & Abst., p. 44, 1988).

A detailed petrographic, microprobe, SEM, and fluid-inclusion study has been conducted in order to define the enrichment and transport processes that have operated in this system. A model is suggested whereby an original ferrogabbro has been hydrothermally altered by late-stage aqueous Cl-sulfide-As solutions, especially enriched in Fe, depositing PGE elements associated with Cu-sulfides.

The initial diabase contained a relatively simple mineralogy of plagioclase, clinopyroxene, and opaques. The alteration is predominately characterized by destruction of the cpx with concomitant crystallization of Fe-rich amphibole and chlorite. The amphiboles are halogen-rich ($\leq$2 wt% Cl). The plagioclase is relatively unaltered. Myrmekitic/pegmatitic intergrowths of quartz, K-feldspar, albite, and halogen-rich apatite are common. Chalcopyrite is the most abundant sulfide and is usually associated with Cl-amphibole, quartz, ilmenite and other sulfides (bornite, galena, and sphalerite). The texture suggests that chalcopyrite was a very late phase. No P magmatic sulfides have been recognized. Intimately associated with chalcopyrite, adjacent to Cl-amphibole or quartz, are very small grains of Pd, Co, Ni, Sb ± Fe, ± S arsenides. SEM-EDS analysis suggests that the chalcopyrite contains dissolved Pt and Au.

P fluid inclusions in quartz commonly contain dxls of an Fe-rich chloride (SEM) and are coeval with P gas inclusions. S inclusions are abundant especially in the quartz and plagioclase. Microthermometry yields Th (no P correction) for the P inclusions that range from 500 to 600°C and from 300 to 400°C of the S inclusions. The quartz/sulfide texture suggests that P fluid inclusions and sulfides formed during the same process.

The evidence suggests that a hydrothermal system developed, probably commencing during late magmatic crystallization, that introduced halogen-rich, sulfide-As aqueous solutions. The Reeser's Summit anomalous PGE zone is the result of deposition by these hydrothermal solutions. (Author's abstract)

BELKIN, H.E., CAVARRETTA, Giuseppe, DE VIVO, Benedetto and TECCE, Francesca, 1988, Hydrothermal phlogopite and anhydrite from the SH2 well, Sabatini volcanic district, Latium, Italy: Fluid inclusions and mineral chemistry: Am. Mineral., v. 73, p. 775-797. First author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092, USA.

The SH2 well (2498.7 m) was drilled vertically in 1982-1983 by an AGIP-ENEL Joint Venture as an exploratory hole to assess the geothermal potential of the area north of Bracciano Lake, Latium, Italy, located in the Sabatini volcanic district. Drill-cutting samples from a thermometamorphic-metasomatic zone (1140-2498.7 m) contain hydrothermal anhydrite ± phlogopite (+ calcite ± pyrite) and other authigenic volatile-rich phases.

Microthermometry of primary and secondary two-phase [vapor (V) + liquid (L)] and multiphase (V + L + crystals) liquid-rich inclusions in anhydrite yields P-corrected Th (Tt) that range from 144 to 304°C and that are generally coincident with measured in-hole T. The fluids have a variable salinity from 0.5 to 14.0 wt% NaCl eq. and also contain Ca^{2+} at least. Rare liquid CO_2-bearing aqueous inclusions have been verified by laser Raman spectroscopy. Also rare liquid hydrocarbons(?) have been observed. Clathrates have been observed upon freezing, and crushing studies reveal noncondensable gas at P >1 atm in some inclusions. Euhedral to subhedral phlogopite crystals (~0.5 to ~2 mm) commonly are zoned and contain solid inclusions of anhydrite and apatite and two-phase (V + L) and multiphase (V + L + crystals) fluid inclusions. Microthermometry of primary two-phase inclusions yields P-corrected Th (Tt) that range from 178 to 298°C and are also generally coincident with in-hole measured T. Freezing studies show a variable fluid salinity (0.2-7.8 wt% NaCl eq.); the fluid contains Ca^{2-} at least. If we assume that the current hydrologic regime existed during anhydrite and phlogopite formation, the P of formation ranged from ~148 to ~220 bars for phlogopite (1600 - ~2500 m) and ~120 to ~220 bars for anhydrite (1300 - ~2500 m). Hence, the phlogopite and other authigenic phases have crystallized from a low P-T, volatile-rich, generally dilute, geothermal solution.

Detailed microprobe analyses of fluid inclusion-bearing phlogopites indicate that they are nearly end member, Fe(T)/(FeT + Mg) = 0.02 to 0.1 and the ^{4}Al per 11 oxygen eq. varies from 1.0 to 1.35. F, BaO, and TiO_2 range from 2.4 to 5.0 wt%, 0 to 3.5 wt%, and 0.1 to 0.89 wt%, respectively, and an Fe^{2+}-F avoidance is observed. Various cation substitutional schemes appear to be operative and are assessed. The dark zones are Fe-rich, but may have more or less F, BaO, or TiO_2 than the light zones. XRF-KEVEX analysis of eight anhydrite samples yield average values (ppm) of Sr = 5500, Ba = 1900, Rb = 250, Ce = 140, and La = 100.

The variation of fluid-inclusion salinities, the phlogopite zoning, and the chemical variation of the anhydrite and phlogopite suggest that different fluids and/or episodic conditions were operative in this geothermal system. (Authors' abstract)

BELLIS, Diane, WOLBERG, D.L. and NORMAN, D.I., 1988, Diffusion and reequilibration in fossil resins: Implications for the study of fluid inclusions in amber (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A393. First author at Chem. Dept., New Mexico Inst. Mining & Mineral Tech., Socorro, NM 87801.

Fluid inclusions in fossil resin (amber) occur in a wide variety of sizes and shapes. Gaseous inclusions appear to be ubiquitous in amber of all genetic types. (We characterize genetic types by the following four end members; 1) primary, those fossilized in situ which have been neither transported nor metamorphosed, 2) secondary, those squeezed out of coals and lignites during coalification processes, 3) tertiary ambers are primary and secondary resins that have been transported and metamorphosed to varying degrees, and 4) quaternary, those resins found in petroleum.)

Inclusions in resins may include any of the following fluids; 2) atmosphere, 2) diagenetic products of the resin matrix, 3) products of the decomposition of trapped biota, and/or 4) products of the maturation of the host sediment. Diffusion of ground water or present day atmosphere into fossil resin will interfere with the interpretation of fluid inclusion data. Diffusion was studied by analyzing fluids released in a high vacuum over time. Composition was determined with a quadrupole mass spectrometer. Samples used for degassng experiments vary from Cretaceous to Oligocene age and are of various genetic types. Composition varies with time and does not appear to represent a diffuson process. Percent composition of the gases released on crushing differs from the degassed. (Authors' abstract)

BENHAMOU, G., ALLARD, P., SABROUX, J.C., VITTER, G., DAJLEVIC, D. and CREUSOT, A., 1988, Oxygen fugacity of gases and rocks from Momotombo volcano, Nicaragua: Application to volcanological monitoring: J. Geophys. Res., v. 93, no. B12, p. 14,872-14,880.

BENNANI, M., 1988, Reconstruction of the hydrothermal paleocirculation in the southern part (Tarmilat-Zguit) of the tin-tungsten bearing area of Walmes (Central Morocco) and its metallogenic significance (in French): Ph.D. dissertation, Inst. Nat'l. Polytech. de Lorraine, 290 pp (+ appendix 75 p.) (in French; English abstract).

The intra- and peri-batholitic quartz-cassiterite/quartz-wolframite ore deposits at Walmes are associated with the multi-stage emplacement of the Walmes granitic pluton, which includes, successively emplaced: biotite El Karit granite (EK); main two-mica granite (p); two-mica granite porphyry (*); and muscovite granite (mu). The EK and p granites are syntectonically emplaced in a very low grade cover of Cambro-Ordovician sandstones and pelites. Mineralogical and fluid inclusion data constrain the lithostatic P at this stage at ~2 kb (0.2 GPa). An overpressure of ~500 b (50 Mpa) corresponds to the development (at ~500°C) of a plastic foliation in the p cortical zones.

The southern Sn-W mineralization occurs in a complex stockwork of quartz veins of several generations (Q2 to Q5). The Q6 generation corresponds to a late overprinting event developed in any of the preceding veins. Most are intra- p but the Zguit veins (Q4 to Q6) are peri-batholithic. The scarce Q2 veins (rarely cassiterite bearing) are correlated with the northern peri-batholitic quartz-muscovite-cassiterite-beryl ores which are contemporaneous with the end of p emplacement. The Q3 veins (rarely cassiterite bearing) are correlated with the northern intra-batholithic Assouel quartz-cassiterite veins, associated with the π emplacement. The Q4 veins are at Tarmilat the main site of deposition of, first, cassiterite and, then, wolframite. Fluid inclusions record a continuous decrease in lithostatic P, from ~1.5 kb (0.15 GPa) at the El Karit stage down to ~1 kb (0.1 GPa) at the Tarmilat/Zguit stage. The Q6 stage records a late P drop, down to hydrostatic P at ~300-400 b (30-40 MPa). There is evidence for a cyclic thermal evolution, characterized by a succession of reheating and subsequent T decrease, probably related to the successive granite intrusions. Each cycle corresponds to a mineralizing event. Elevated T (550°-500°C) are recorded for the beginning of the earlier El Karit and Assouel/Q3 stages. Cassiterite deposition typically took place at 450°C-400°C. Later stages developed at lower T (350°-300°C). Hydrothermal fluids are of low salinity from the beginning. There is no evidence of the contribution of a magmatic fluid. The involved fluids have a significant content of volatiles (C-O-H-N) fluids and are evidently of metamorphic derivation; their dilution by cooler purely aqueous fluid is clearly responsible for cassiterite or wolframite deposition. At least four recharging events in C-O-H-N components are recorded. (Author's abstract)

Note: See also 1988 Ph.D. by Boutaleb, this volume. (E.R.)

BERDNIKOV, N.V. and KARSAKOV, L.P., 1988, Control of the fluid regime of metamorphism based on inclusions in minerals, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 97-103 (in Russian).

BERGER, G., SCHOTT, J. and GUY, Ch., 1988, Behavior of K, Rb and Cs during basalt glass and olivine dissolution and chlorite, smectite and zeolite precipitation from seawater: Experimental investigations and modelization between 50° and 300°C: Chem. Geol., v. 71, p. 297-312.

BERMAN, R.G., BROWN, T.H., and PERKINS, E.H., 1988, Geo-calc update: Software for calculation of pressure-temperature-XCO_2-activity phase diagrams (abst.): GAC/MAC Program with Abstracts, v.13, p.A9.

BERNARD, A. and SYMONDS, R.B., 1988, The speciation of trace metals in high temperature gases from Usu volcano, Japan (abst.): EOS, v.69, p.514.

BERNDT, M.E., SEYFRIED, W.E., Jr.. and COOK, S.S., 1988, Trace element evidence for formation of a Cl-rich mineral in mid-ocean ridge hydrothermal systems (abst.): EOS, v.69, p.464. First author at Dept. of Geo. and Geophy., Univ. of Minn., Minneapolis, MN, 55455.

The data suggest that the source of B, Li, Rb, and K enrichments in vent fluids is similar and related entirely to rock alteration processes. We propose that a phase such as $Fe_2(OH)_3Cl$ precipitates from hydrothermal fluids during alteration of a magnetite and olivine bearing assemblage at relatively low P and high T. (From the authors' abstract)

BERNER, R.A. and LANDIS, G.P., 1988, Gas bubbles in fossil amber as possible indicators of the major gas composition of ancient air: Science, v.239, p.1406-1409. First author at Dept. Geol. and Geophy., Yale Univ., New Haven, CT 06511.

Gases trapped in Miocene to Upper Cretaceous amber were released by gently crushing the amber under vacuum and were analyzed by quadrupole mass spectrometry. After discounting the possibility that the major gases N_2, O_2, and CO_2 underwent appreciable diffusion and diagenetic exchange with their surroundings or reaction with the amber, it has been concluded that in P bubbles (gas released during initial breakage) these gases represent mainly originally ancient air modified by the aerobic respiration of microorganisms. Values of $N_2/(CO_2 + O_2)$ for each time period give consistent results despite varying O_2/CO_2 ratios that presumably were due to varying degrees of respiration. This allows calculation of original oxygen concentrations, which, on the basis of these preliminary results, appear to have changed from greater than 30% O_2 during one part of the late Cretaceous (between 75 and 95 million years ago) to 21% during the Eocene-Oligocene and for present-day samples, with possibly lower values during the Oligocene-Early Miocene. Variable O_2 levels over time in general confirm theoretical isotope-mass balance calculations and suggest that the atmosphere has evolved over Phanerozoic time. (Authors' abstract)

BERTRAND, Philippe, PITTION, J.-L. and BERNAUD, Christine, 1986, Fluorescence of sedimentary organic matter in relation to its chemical composition: Org. Geochem., v. 10, p. 641-647.

BERZENINA, E.F., KICHURCHAK, V.M., BARANOV, P.N. and KNYAZEV, E.G., 1988, A new (Krasnokutsk) Massif in western Azov Sea area: Geokhim. Rudoobraz, v. 16, p. 57-61 (in Russian). Authors at Dnepropetr. Gorn. Inst., Dnepropetrovsk, USSR.

Geological, petrographical, and geochemical features are described of the Krasnokutsk granitic massif, outcropping in two areas of the Ukranian Shield in the western Azov Sea region. Granites of the massif yielded a K-Ar age of 2.0-2.1 Gyr and according to the Zavaritskii petrochemical coefficients classify as acidic leucocratic rocks supersaturated with SiO_2 and Al_2O_3 and having K/Na ratios ~1. The granites are palingenetic and originated from the melting of ancient, differentiated continental crust. Post-magmatic alteration (greisenization, albitization, and pegmatitization) is widespread in the massif. Based on fluid-inclusion studies, magma crystallization began at 740° and the fluids associated with the melt had a H_2O-CO_2 composition. Pneumatolytic-hydrothermal and hydrothermal processes occurred at 460-160°. (C.A. 110: 79606y)

BETHKE, C. M., 1988, Origin of long-range brine migration across the North American craton (abst.): EOS, v.69, p.470.

BETHKE, C.M., HARRISON, W.J., UPSON, Craig, and ALTANER, S.P., 1988, Supercomputer analysis of sedimentary basins: Science, v.239, p.261-267, First author at Dept. of Geol., Univ. of Illinois, Urbana, IL 61801. USA.

Geological processes of fluid transport and chemical reaction in sedimentary basins have formed many of the earth's energy and mineral resources. These processes can be analyzed on natural time and distance scales with the use of supercomputers. Numerical experiments are presented that give insights to the factors controlling subsurface P, T, and reactions; the origin of ores; and the distribution and quantity of hydrocarbon reservoirs. The results show that numerical analysis combined with stratigraphic, sea level, and plate tectonic histories provides a powerful tool for studying the evolution of sedimentary basins over geologic time. (Authors' abstract)

BIGNELL, N. and BEAN, V.E., 1988, A fixed point on the pressure scale: Carbon dioxide vapor pressure at 273.16 K: Metrologia, v. 25, p. 141-145. First author at CSIRO, Div. Applied Physics, Sydney, Australia 2070.

The vapor P of carbon dioxide in equilibrium with the liquid at 0.01°C has been measured; the value is found to be 3.48608 ± 0.00017 MPa. Results were found to depend on the purity of the carbon dioxide. The relatively simple procedures reported herein produced carbon dioxide samples of sufficient purity to be suitable for use of this vapor-P value as a P fixed point. (Authors' abstract)

BILAL, Ahmad, 1988, Petrology of ultramafic xenoliths transported by the basalt of Syria (abst.): 12th Reunion des Sci. de la Terre, 27-29 April, 1988, Abstracts, p. 16 (in French). Author at Univ. Damascus, B.P. 9487, Damascus, Syria.

Intense volcanic activity, poorly dated but probably Cretaceous to Quaternary with a peak in the Tertiary, affected much of Syria. Olivine basalts, hawaiites, mugearites and trachytes transported a variety of xenoliths including peridotite, pyroxenite and associated hydrated types. Fluid inclusions in xenoliths from Djebel Al-Arab, Djabel Nabi Mata, Kadmous and Jubats contain CO_2. Those from Djabel Nabi Mata are the densest. Using T calculated from the model of Wood and Banno (1973), P and depth for the xenoliths have been determined as follows:

	Th °C max	Density $g\,cm^{-3}$ max	T °C max	P kb max	Depth km max
Dj.Al-Arab	-39	1.1	1177	12.8	42.2
Dj.Nabi Mata	-47	1.12	1217	15.1	49.8
Kadmous	-41	1.107	1206	13.4	44.2
Jubats	-35	1.02	1151	10.5	34.6

(Author's abstract, translated and abbreviated by C.J. Eastoe)

BILAL, B.A. and LANGER, P., 1988, Complex formation of trace elements in mineral-bearing solution under hydrothermal conditions (abst.): Terra cognita, v. 8, p. 182. Author at Hahn-Meitner-Inst. Berlin GmbH, Berlin, FRG.

Chemically similar trace elements (e.g., lanthanides) are fractionated in most minerals, particularly Ca-minerals (e.g., fluorite) in a certain manner. Normalized to their content in chondrites, the lighter members of the series are more abundant than the heavier, where the differences between La and Tb is more distinct than between Tb and Lu. Such fraction seems to be a good indicator for the mineral genesis, provided we know the physicochemical behavior of the trace elements as a function of the conditions of the mineral formation or mineral metamorphosis (P, T and X). The most important processes determining this behavior are the complex formation of the trace elements in the mineral-bearing fluid phase and their distribution between this phase and the crystallizing mineral. Previous studies in our laboratory under normal P-, T-conditions showed that in a fluorite-bearing model system only the ligands F^- and OH^- form lanthanide complexes of significant stability, whereas Cl^-, SO_4^{2-} and HCO_3^- play rather minor roles. The complexation by means of F^- and OH^- has been studied at T up ot 200°C and P up to 1 kbar and the availability of the different lanthanide species which may co-crystallize with fluorite has been calculated as functions of T, P and pH of a fluorite-bearing system. The question is discussed which species at which T, P and pH must be considered to obtain at least qualitative agreement with the fraction observed analytically in fluorite samples. (Authors' abstract)

BIRD, D.K., CHO, M., JANIK, C.J., LIOU, J.G. and CARUSO, L.J., 1988, Compositional, order/disorder, and stable isotope characteristics of Al-Fe epidote, State 2-14 drill hole, Salton Sea geothermal system: J. Geoph. Res., v. 93, no. B11, p. 13,135-13,144. First author at Dept. Geol., Stanford Univ., Stanford, CA.

Epidote ($Ca_2Fe_3Si_3O_{12}(OH)$-$Ca_2Al_3Si_3O_{12}(OH)$) is a common hydrothermal mineral in metasediments and veins at depths >900 m in the State 2-14 drill hole of the Salton Sea geothermal system. When compared to the reservoir fluid from the December 1985 flow test, the derived fractionation of hydrogen isotopes between epidote and the geothermal brine is -19‰ at 1867 m and ~340°C. This value is in accord with published experimental hydrogen isotope fractionations between iron-rich epidote and aqueous electrolyte solutions. Therefore, considering the complexity of the Salton Sea brine, the isotopic T is similar to the inferred downhole T. (From the authors' abstract by E.R.)

BIRD, D.K., MANNING, C.E. and ROSE, N.M., 1988a, Mineralogic and isotopic constraints on the regional hydrology of the Skaergaard magma-hydrothermal system, east Greenland (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A344-A345. Authors at Dept. Geol., Stanford Univ., Stanford, CO 94305.

Early Tertiary volcanic rocks (Lower Basalts) exposed east of the Skaergaard intrusion constitute a fluid source region for meteoric groundwaters that circulated through and reacted with the cooling gabbro. The Lower Basalts define a paleo-aquifer 3 to 5 km deep capped by 0.5 km of tuffs and underlain by sediments and gneisses. This aquifer consists of a ~ 1.5 km succession of lavas, hyaloclastites, pillow breccias, as flows and tuffaceous sediments that are crosscut by dikes, sills, and faults. At 4 to 6 km east of the Skaergaard the volcanics are intruded by the Miki Fjord Macrodike, a 0.4 to 1.5 km wide and >15 km long composite gabbroic dike complex that represents a potential aquitard to lateral fluid flow in the aquifer. At distances between 1.5 to 20 km east of the Skaergaard the lower portions of the aquifer are altered to low-grade mineral assemblages including groundmass chlorite + epidote + albite and drusy pore filling epidote + quartz + prehnite + microcline + calcite. In the lower portions of the aquifer epidote is absent at distances >20 km, and it occurs in the upper portions only where sills are abundant. Between 3 and 12 km from the Skaergaard $\delta^{18}O$ quartz is 8.3-10.5‰ and $\delta^{18}O$ epidote is 2.4-3.3‰, and at <2 km $\delta^{18}O$ is 6.9-7.1‰ and $\delta^{18}O$ epidote is 0.7-1.1‰; the steep gradient in $\delta^{18}O$ between 2 to 3 km from the Skaergaard appears to correlate with increase in fluid inclusion T from <250°C to 250-300°C near the intrusion. Throughout the lower portions of the aquifer calculated values of $\delta^{18}O$ fluid in equilibrium with quartz are between 0 and -2‰, and freezing point depressions indicate that the aquifer fluids were <2 wt. % NaCl eq. solutions. In the Miki Fjord Macrodike (MFM) the lowest values of $\delta^{18}O$ plagioclase occur in centers of metabasalt xenoliths ($\delta^{18}O$(Plag) = 3.1-4.2‰) and adjacent layered gabbros ($\delta^{18}O$(Plag) = 4.0-4.2‰), whereas in massive gabbros without xenoliths $\delta^{18}O$ plagioclase is 5.5-5.8‰. These observations, together with $\delta^{18}O$ basalt reported by Taylor and Forester (Jour. Pet. 1979), suggest that the hydrologic barrier represented by the MFM did not have a significant [e]ffect on the geochemical characteristics of the aquifer. The MFM was intruded late relative to the regional mineralogic and isotopic alteration and the altered basalts provided a lithologic reservoir of hydrated and ^{18}O depleted material that was locally stoped into and partially assimilated by the cooling macrodike magma. (Authors' abstract)

BIRD, D.K., MANNING, C.E. and ROSE, N.M., 1988b, Hydrothermal alteration of Tertiary layered gabbros, east Greenland: Am. J. Sci., v. 288, no. 5, p. 405-457. See previous item. (E.R.)

BISCHOFF, J.L. and ROSENBAUER, R.J., 1987 - See Appendix

BISCHOFF, J.L. and ROSENBAUER, R.J., 1988, Liquid-vapor relations in the critical region of the system NaCl-H_2O from 380 to 415°C: A refined determination of the critical point and two-phase boundary of seawater:

Geochimica Cosmo. Acta, v. 52, p. 2121-2126. Authors at U.S. Geol. Survey, Menlo Park, CA 94025, USA.

Pressure-temperature-composition (P-T-x) relations for coexisting vapor and liquid phases in the system NaCl-H_2O were determined experimentally in the critical region from 380 to 415°C. The results provide much improved control on the P-T-x critical line in this region. The critical point of seawater (3.2 wt% NaCl solution), which is bracketed in the present study, is at 407°C and 298.5 bar. In addition, the P-T two-phase boundary of seawater was redetermined. These results provide increased precision and accuracy for theoretical models of critical phenomena in this important two-component system and of the limiting P-T conditions of seawater in seafloor geothermal systems. (Authors' abstract)

BLANCO, Alonso and GOODELL, P.C., 1987, Alabandite and associated minerals, Mina Preciosa, Puebla, Mexico: Boletín de Mineral., v. 3, no. 1, p. 57-77. First author at Dept. Geol. Sci., Univ. Texas at El Paso, El Paso, TX 79968.

Alabandite (MnS) is a rare mineral, the genesis of which has not been well studied. The occurrence of this mineral at Mina Preciosa, Puebla, Mexico, is among the most (if not the most) famous localities of this mineral in the western hemisphere, and probably in the world. This study is an initial description of the environment of formation of alabandite at Mina Preciosa, Puebla.

Coarse crystalline calcite is present, but its paragenesis could not be established. T and mineralization determined from fluid inclusion studies varied from averages of 320°C for calcite, 308°C for sphalerite, and 231°C for late stage coarse crystalline quartz. Trace element studies revealed that Ag is the major element of economic interest. Small amounts of Au and base metals are also present. Alabandite appears to have formed from mesothermal to epithermal processes, probably from connate or meteoric waters. These waters may have been generated during the Pliocene volcanism. Alabandite precipitation is dependent upon a high manganese and sulfur concentration correlated with a reducing environment. (From the authors' abstract by H.E.B.)

BLASCH, S.R., and COVENEY, R.M. Jr., 1988, Goethite-bearing brine inclusions, petroleum inclusions, and the geochemical conditions of ore deposition at the Jumbo mine, Kansas: Geochim. Cosmo. Acta, v.52, p.1007-1017. First author at Dept. of Geosci., Univ. of Missouri-Kansas City, Kansas City, Kansas City, MO 64110-2499, USA.

Petroleum-bearing fluid inclusions occur in sphalerite, calcite, dolomite, and barite at the Jumbo mine, a Mississippi Valley-type deposit in eastern Kansas. In addition to petroleum, Na-Ca-Mg-Fe chloride brines were present during deposition of calcite and sphalerite in which P inclusions contain >23 eq wt.% NaCl. Dolomite-and barite-hosted inclusions are more dilute, possibly because of mixing between hydrothermal fluids and groundwater during mineralization. P oil inclusions in sphalerite have Th between 85 and 95°C. Aqueous inclusions have Th values ranging from ≈90 to 130°C for sphalerite to below ≈50°C for barite.

P brine inclusions in calcite at the Jumbo mine contain goethite, apparently as a dm (although it is possible that the goethite formed as a result of diffusion of H_2 from the inclusions like the hematite dm described by Roedder and Skinner, 1968, from Bingham, Utah). Goethite has also been tentatively identified in inclusions from the Fletcher mine of Missouri. If goethite is a true dm phase, it implies the presence of oxidized and dilute groundwater (e.g., by dilution or cooling or ore fluids, or oxidation of organometallic complexes that may have transported metal constituents). (Authors' abstract)

BLATTNER, P. and LASSEY, K.R., 1988, Isotope alteration profiles by advective infiltration of the lithosphere: Causes and effects (abst.): Terra cognita, v. 8, p. 254. First author NZ Geol. Survey, Lower Hutt, NZ.

The continued infiltration of extraneous fluid into a permeable solid along a 1-dimensional (1-D) trajectory leads to systematic alteration of stable isotope ratios in the aquifer solid. For this fundamental scenario of geochemistry, only the simplified model of Spooner et al. (1977) has been available to date.

We demonstrate here an analytic solution to the problems of mass balance and exchange rate limitations in 1-D infiltration. Model simulations of infiltration into uniform rock of initially uniform isotope composition (e.g., oxygen isotopes) yield characteristic profiles of $\delta^{18}O$ (solid) vs infiltration distance. These δ vs distance profiles are uniquely determined by the dimensionless quantity N_D (Damköhler number), which is the ratio of the isotope exchange rate constant κ over the interstitial fluid velocity q, multiplied by the infiltration distance L.

For infiltration at constant, uniform T and therefore $\Delta^{18}O$, δ vs distance profiles corresponding to different N_D values display a geometrically simple evolution. For infiltration profiles of constant non-uniform T and Δ their geometric interrelationships become distorted in an exactly predictable way. For high N_D (high κ), a geochemical front, retarded on account of concentration-corrected porosity ("O porosity," "Sr porosity") marks the end of an advance regime of possible δ-transients, and reveals the final steady state profile for a given infiltrating fluid. For lower N_D, δ values of rock drop away gradually with time, partly simulating zero-dimensional (0-D) "box" or "mixed" models, e.g., of Taylor (1977) and Blattner (1985).

The 1-D approach predicts a decoupling of O and Sr, and O and C isotope fronts in various systems, as well as (for different reasons) a decoupling of isotope alteration fronts for minerals with different exchange rate constants for isotopes of a given element. In both cases 0-D treatments could therefore be misleading. In general, the 1-D approach leads to an appreciation of the geochemical buffering capacity of the lithosphere with regard to fluids. (Authors' abstract)

BLOM, K.A., 1988, Subsolidus migmatization in high-grade meta-tuffs (Kurkijärvi, southwest Finland): Lithos, v. 21, p. 263-278. Author at Westlandgracht 67^{II}, NL-1058 TN Amsterdam, The Netherlands.

The phenomenon of migmatization was studied in Precambrian metavolcanic gneisses of calc-alkaline chemistry, outcropping along a prograde amphibolite/granulite facies transition in the West Uusimaa Complex of SW Finland. This paper discussed one of the studied gneiss levels (a garnet-bearing Qtz/Plag/Ksp/Bio-gneiss) which was observed to transect the metamorphic isograd pattern at almost right angle. The gneiss was studied for structures, whole-rock chemistry (major, trace and REE), mineral content, microtextures, plagioclase anorthite content and fluid inclusions. Data concerning the latter four subjects are presented.

Migmatization proved to: (1) have occurred parallel to compositional banding of the rocks; (2) have produced identical leucosome/melanosome/mesosome mineral parageneses; (3) have initiated feldspar/garnet-poikiloblasthesis (and occasionally biotite porphyroblasthesis) in leucosome, and biotite-/garnet-poikiloblasthesis in melanosome; (4) have caused entrapment of unstrained quartz blebs carrying isolated (P) two-phase pure H_2O fluid inclusions of unique filling degree range in the above-mentioned feldspar- and garnet-poikiloblasts; (5) have occurred post-D_1/pre-D_2, synchronous to amphibolite-facies metamorphism, in the subsolidus regime; (6) have been affected by D_2 in the way of localized mylonitization of the melanosome, and quartz migration (exudation) from adjacent mesosome into leucosome; and (7) have had some control by the biotite content of the original compositionally banded rock.

Initial leucosome formation appears to have been controlled by the pre-leucosome biotite content: the recalculated modal biotite content of the leucosome/melanosome combination conspicuously is in the range of 5-20 vol.% of biotite. Final extent of the leucosome shows on its turn a marked correlation with mesosome modal biotite content.

Because leucosomes occur carrying a recalculated modal biotite content equalling adjacent mesosome biotite content, a second factor is held responsible for the onset of migmatization in the buried and sheared rock: deficient water balance. Migmatization, initiated at P/T conditions fit for feldspar recrystallization and almandine formation, was induced during prograde metamorphism to cancel an established zonation in water P or water content parallel to compositional banding. Zones of low $P(H_2O)$ or wt.% H_2O thereby were converted into leucosomes, while zones of higher $P(H_2O)$ or wt.% H_2O remained unaffected (and became mesosome). That $X(H_2O)$ did not vary at the onset of migmatization is recorded in the isolated pure H_2O fluid inclusions contained in the quartz blebs enclosed in the studied leucosome- and melanosome-poikiloblasts. Restore of water balance (either by internally controlled factors or externally introduced ones) halted migmatization and its obliteration of compositional banding. (Author's abstract)

BLOMQUIST, P.K, PERRY, R.V. and BEATY, D.W., 1988, The geology of "Sherman-type" Ag-Pb-Zn-Ba deposits in the Leadville Formation, Spring Creek area, central Colorado (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A336-A337. First author at Dept. Geol., Colorado Sch. Mines, Golden, CO 80401.

The term "Sherman-type ore" was first applied to a group of deposits 10-15 km E of Leadville, CO, which have distinctive mineralogy, mineral chemistry and paragenesis (Behre, 1953). A group of similar deposits was recently recognized in the general area of Spring Creek, 60 km SE of Leadville.

The Spring Creek deposits have somewhat variable mineralogy, but typically consist of bladed early white barite, galena, light-colored sphalerite, and local minor quartz, tetrahedrite, and pyrite. A considerable amount of jasperoid is also present in the Spring Creek area. The sulfide deposits occur primarily in the Leadville Formation, but have also been recognized in the Gilman Sandstone, the Dyer Dolomite, and the Manitou Dolomite. The ore is characteristically high -Pb (10-20%), high-Zn (5-10%), high-Ag (200-1000 ppm), and low-Au (<0.02 ppm). Fluid inclusions indicate T = 182-248°C (bar.), 141-181°C (sph.), and 167-210°C (qtz.). Isotopic analyses for $\delta^{18}O$ (bar: +11.9 to +16.1) and $\delta^{34}S$ (bar: +9.2 to +15.3, gal: -3.1 to +4.0, sph: +6.1 to +9.8, py: +9.2) suggest ore deposition from a basinal brine. Recent field work has documented paleokarst solution features in the Leadville, Fm., their relationship to two unconformities in the Leadville, and their importance as an ore host. Geological relations involving igneous rocks, the deformation of the Sawatch Anticline, and nearby sedimentary basins constrain the timing of the mineralization event(s?).

Because Sherman-type ore deposits have now been recognized to be regionally distributed, a regionally-extensive mineralization process is indicated. (Authors' abstract)

BLOMQVIST, R.G., LAHERMO, P.W., HALONEN, S., FRAPE, S.K. and ILMASTI, M., 1988, Brines in the Precambrian crystalline bedrock of Finland (abst.): Chem. Geol., v. 70, p. 158. Authors at Geol. Survey of Finland, SF-02150 Espoo, Finland.

During areal mapping of deep groundwater in the Precambrian crystalline basement of Finland, saline waters, and in some localities, even brines (TDS >100 g/L), have frequently been found at depths below a couple of hundred meters. The sampling method used is a new one and allows a continuous profile of water to be taken, even from small diameter (46 mm) drill holes.

The saline waters are hosted by widely different geological formations and located in different parts of the country. The most saline water encountered so far (TDS: 180 g/L) is located in a massive serpentinite in a mica schist environment in Juuka, eastern Finland. The brine, found in the drillhole at depths from 800 to 1100 m, is of Na-Ca-Cl type. A hole drilled near the city of Pori in SW Finland penetrates flat-lying unmetamorphosed sandstone sequences in a graben formation of Precambrian age. The groundwater is of Ca-Cl type with TDS 120 g/L at hole bottom (600 m). A drill hole in Ylivieska, in the middle of the country, is located in a layered mafic-ultramafic intrusion. The water at hole bottom is of Ca-Na-Mg-Cl type with TDS exceeding 50 g/L.

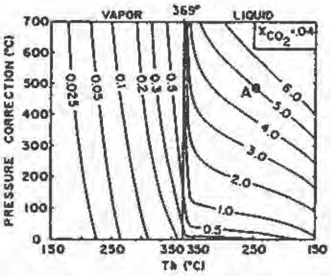
The tritium contents in the saline waters are low. The stable isotope values deviate clearly to the left of the GMWL line (in the holes above: ^{18}Odelta = -11.5, -8 and -13‰, and ^{2}Hdelta = -20 - -5, -50 - -40, -60 - -40‰, respectively). The results are indicative of long-lasting water-rock interaction. (Authors' abstract)

BOBYLEV, I.B., ANFILOGOVA, G.I. and ANGILOGOV, V.N., 1987, Influence of CaO on low-temperature liquid immiscibility in the system leucite-fayalite-silica: Geokhimiya, no. 6, p. 787-797 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 1, p. 30-39).

BODNAR, R.J., 1988a, Pressure correction diagrams for water-carbon dioxide fluid inclusions (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A343. Author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Except in the case of fluid inclusions trapped on the solvus, a P correction must be added to the Th to obtain the Tf. For a given fluid inclusion composition, the magnitude of the P correction depends on (1) Th, (2) the mode of homogenization, (3) the slope of the isochore and, (4) the formation pressure (Pf). P correction diagrams of H_2O-CO_2 fluid inclusions with compositions ranging from pure H_2O to pure CO_2 and trapping conditions <10 kbar have been constructed. For each composition, the density corresponding to a given T and P on the H_2O-CO_2 solvus was calculated using a modified Redlich-Kwong (MRK) equation of state. The projection of that constant density line in P-T space (isochore) was then calculated with the MRK by iteration.

The accompanying illustration shows P correction calculated for an H_2O-CO_2 fluid inclusion containing 4 mole % CO_2. Contours represent isobars of trapping P in kilobars. The maximum Th (369°C) represents the CP for this composition; homogenization to the vapor phase (left side of diagram) and to the liquid phase (right side of diagram) occur at T less than the CP. As an example of the use of P correction diagrams, consider an H_2O-CO_2 fluid inclusion that contains 4 mole % CO_2, homogenizes to the liquid phase at 250°C, and was trapped at 5 kilobars (point "A"). The P correction, or that amount which must be added to Th to obtain the trapping T, is ~500°C, giving a formation T of ~750°C. (Author's abstract) Continued next page.



BODNAR, R.J., 1988b Use of fluid inclusions in precious metals exploration (abst.), in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 743. Author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ.

One-and-a-half-page abstract; see Bodnar, 1987b, in Fluid Inclusion Research, v. 20, p. 39-40. (E.R.)

BÖHLKE, J.K., 1988a "Divergent" metasomatic reactions with a "common" fluid (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 31. Author at CMT-205, Argonne National Lab., Argonne, IL 60439.

Contrasting metasomatic high-variance phase assemblages occur where discordant gold-bearing quartz veins cross lithologic boundaries in the Sierra Nevada metamorphic belt, California. For example, sericite and Mg-Fe carbonate solid solutions are major alteration phases adjacent to veins crossing ultramafic rocks (low Al/[Mg + Cr], low Fe/Mg); whereas albite and pyrite are major phases in altered granitic rocks (high Al/[Mg + Cr], high Fe/Mg). These assemblages apparently formed in equilibrium with pore fluids that were rock-dominated with respect to relatively immobile constituents (e.g., Al, Cr, Fe, Mg) and vein fluid-dominated with respect to mobile constituents (e.g., Na, K, CO_2, H_2S). The sericite and carbonate solid solutions were stable with respect to albite and pyrite, respectively, where local wall rocks supplied cations which tended to decrease the thermodynamic activities of muscovite and siderite components. Both assemblages are consistent with partial equilibrium between altered rocks and a "common" through-flowing CO_2-rich vein fluid with constant CO_2:H_2S:H_2 and Na:K:H ratios at constant T and P. The veins fluid is inferred to have acquired its major element ratios by reactions with the average, or most abundant, wall rocks along its flow path, and to have caused "divergent" reactions where it encountered wall rocks with compositions far from the norm.

In principle, contrasting high-variance asemblages may be useful in determining common fluid characteristics in a variety of metasomatic systems in lithologically heterogeneous terranes. Also, divergent reactions of a common fluid with different wall rocks may provide an explanation for apparent anomalies or reversals in metasomatic fluxes in some otherwise simple systems. (Author's abstract)

BÖHLKE, J.K., 1988b Carbonate-sulfide equilibria and "stratabound" disseminated epigenetic gold mineralization: A proposal based on examples from Alleghany, California, U.S.A.: Applied Geochem., v. 3, p. 499-516. Author at CMT-205 Argonne Nat'l. Lab., Argonne, IL 60439, USA.

"Stratabound" disseminated pyritic Au ore bodies were produced by reactions between wall rocks and through-flowing fluids in Mesozoic epigenetic Au quartz vein systems in the Sierra Nevada metamorphic belt. Equilibrium relations among Fe-bearing carbonate and sulfide minerals were critical in determining which rock types were likely to host disseminated mineralization along portions of discordant veins. The compositions of metasomatic carbonates in hydrothermally altered wall rocks at Alleghany, California, U.S.A., were largely predetermined by the relative proportions of Fe, Mg and Ca in the unaltered wall rocks. It is proposed that the CO_2-rich vein fluid responsible for the alteration and mineralization was partially buffered with respect to $H_2S/CO_2/H_2$ ratios by equilibrium between pyrite and $Mg_{0.4}Fe_{0.6}CO_3$ (+ graphite?) as it traversed and altered intermediate volcanic and sedimentary rocks. This fluid then locally reacted with lower Fe/(Fe + Mg) rocks to form Fe-bearing dolomite + magnesite assemblages, and reacted with higher Fe/(Fe + Mg) rocks to form ankerite + pyrite assemblages. Au precipitated from saturated solutions of bisulfide complexes partly in response to fluid desulfidation and reduction caused by the pyritization reactions. Carbonate-sulfide equilibria are capable of approximately buffering the carbonate-sulfide ratios of CO_2-rich vein fluids ($fCO_2 > 10^{2.8}$ at 325°C, 200 MPa or 2000 bar). The Alleghany fluid ($fCO_2 \approx 10^{3.2}$, or ~10 mol % CO_2) had a molar CO_2/H_2S ratio of approximately 10^3, assuming graphite saturation. At lower CO_2 fugacities, Fe-bearing silicates entered the buffering assemblages. Carbonatization reactions could potentially de-sulfidize some wall rocks, releasing S (and associated metals?) to the fluid. This would be most likely to occur in pyrite-bearing mafic and ultramafic rocks and some argillites. (From the author's abstract)

BÖHLKE, J.K., COVENEY, R.M., Jr., RYE, R.O. and BARNES, Ivan, 1988, Stable isotope investigation of gold quartz veins at the Oriental mine, Alleghany district, California: U.S. Geol. Survey Open-File Rept. 88-279, 24 pp. First author at Argonne Nat'l. Lab., Argonne, IL 60439.

The $\delta^{18}O(H_2O)$ of the hydrothermal fluids must have been buffered in large part by exchange with the metamorphic rocks. Hydrogen isotope data indicate that vein quartz samples contain mixed populations of fluid inclusions. There is some evidence that inclusions with higher CO_2/H_2O ratios have higher $\delta D(H_2O)$ values. The highest $\delta D(H_2O)$ values are consistent with a metamorphic origin of the CO_2-bearing fluids, but a meteoric origin cannot be ruled out on this basis alone; however, if the higher $\delta D(H_2O)$ values do correspond to unexchanged Cretaceous meteoric water, then the fluid inclusions with low $\delta D(H_2O)$ values must have been trapped a long time after the main stages of alteration and vein formation. The fluids responsible for hydrothermal alteration (carbonatization and steatization) had higher $\delta D(H_2O)$ values than the fluids responsible for much of the serpentinitization. This is consistent with, but does not confirm, the interpretation that serpentinization and Au mineralization occurred independently. Most of the isotopic data are consistent with the interpretation that the "main stage" hydrothermal fluid had concentrations of sulfide > sulfate, and $CO_2 > CH_4$, and that the bulk of the sulfide and carbonate deposition was not accompanied by large excursions in the oxidation state of the fluid. No direct isotopic evidence can be cited yet to support the contention that H_2 gas from serpentinite had a role in precipitating high-grade Au ores in the veins. There is no isotopic evidence for extensive fluid unmixing. S, C, and H isotope data all are consistent with the possibility that fluids from shallower reservoirs entered the veins after much of the hydrothermal alteration and vein filling by CO_2-bearing fluids from deeper sources took place. (From the authors' Conclusions by E.R.)

BOIRON, M.C., 1988, Gold-bearing arsenopyrite ores spatially associated to the Marche-Combrailles shear zone (Massif Central, France): Geology and genesis (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 252-254. Author at CREGU, BP 23,54501 Vandoeuvre les Nancy Cedex, France.

A chlorite-albite-anatase (± quartz, calcite, phengite, pyrite) alteration resulted from a pervasive circulation of aqueous fluids, having low salinities (1-4 wt. % eq NaCl) at ~250-310°C. Arsenopyrite deposition occurred at ~180 ± 20°C, at low pH as indicated by the complete alteration of the host rocks into a quartz-K-micas-ankerite association, at rather low fO_2. Low T (90 ± 20°C) fluids circulated at last within the deposit during more discrete reactivation of the system, and are responsible for the crystallization of calcite and quartz, as late infillings of veins and tension cracks. (From the author's abstract)

BOIRON, M.C. and CATHELINEAU, M., 1987, Contrasted behavior of Au, and U in granites at the hydrothermal state: The role of fO_2 and pH (abst.): Societa Italiana di Mineralogia e Petrologia, Conf. "Granites and their surroundings," Verbania, Italy, 29 Sept.-3 Oct. 1987, Abstracts, p. 62-63. First author at Lab. Pétrol. de la Surface, Univ. Poitiers, UA CNRS 721, 40, avenue du Recteur Pineau, 86022 Potiers Cedex, France.

Parts of the Hercynian belt in Europe give imporant metallogenic districts for Au and U. Most of the deposits were discovered in the vicinity of major shear zones (S.Z.): the South Armorican S.Z., the Limousin S.Z. (Arènes-Quzilly, Bussières-Madeleine, ...), the Marche-Combrailles S.Z. Mineralizations are located both inside granitic rocks and in the surrounding metamorphic rocks. In spite of numerous similarities (age around 280-315 Ma, presence of peraluminous granites, fluid circulation related to tardihercynian activity, T ~150 to 350°C, ...) location of Au deposits on one hand, and U on the other hand, is distinct. No U districts have produced significant amounts of Au and vice versa. This spatial distinction may be related to the different source rock location respective to the two metals. However in many cases, potential source rocks of both elements are either observed together, in the vicinity of the deposits, or unknown. Thus, it has been considered that the hydrothermal stage is certainly a key in the understanding of the contrasting behavior of U and Au, firstly because most of these deposits were formed under hydrothermal conditions. The purpose of this work was to investigate the role of fO_2, fS_2 and pH and complexing agents as factors controlling the ability of hydrothermal fluids for transport and deposition of U and Au in granites, following the same approach than Dubessy et al. (Bull. Min., 110, 261, 1987) for U and Sn-W.

a) In most of U deposits, pitchblende is associated with pyrite, or hematite + pyrite in the veins while the stable mineral assemblage in the host rocks is: quartz-muscovite-feldspars-hematite. Discrete crystallization of authigenic K-micas can occur before and/or during pitchblende depositon. Fluids are considered to be mostly aqueous, poorly saline, with a relatively low CO_2 content (<0.5 moles %) which does not exclude otherwise significant amounts of carbonates in solution for U-transport. fO_2 is high and higher than that fixed by the hematite-pyrite-magnetite triple point. pH is probably nearby neutral.

b) In Au(As-Sb) deposits, two types of fluids may be distinguished (Bril, 1983, Hubert, 1986, Boiron, 1987, and work in progress): (1) high T (300-400°C) fluids which are in some cases aqueous, but more frequently belong to the CO_2-H_2O (NaCl) system. In general CH_4 content is low; or (2) lower T fluids (150-250°C) which are dominantly aqueous, and poorly saline (Marche-Combrailles zone, Boiron, 1987).

In most cases, strong K-mica (phengite, or illite) alteration occurs, which indicates a strong disequilibrium between fluids and host rocks, and rather low pH. fO_2 is low, but the frequent pyrrhotite instability during major Au-deposition, the low CH_4 content in the fluids, indicate that fO_2 is probably higher than the Ni-NiO buffer, and that fS_2 is high (join pyrite-arsenopyrite). Thus, the fO_2 is probably higher than in Sn-W deposits for instance, where Ramboz et al., 1985, and Dubessy et al., 1987, demonstrated low fO_2 around those fixed by the Ni-NiO and Q-F-M buffers.

Considering the experimental data on U and Au solubility (Nguyen, 1985; Seward, 1973; Henley, 1973) and metal species in fluids, it is clear that under the above mentioned conditions U and Au cannot be mobilized and deposited together. U transport requires especially higher fO_2 values than those which are necessary for an effective solubilization of Au. On the contrary, pH under deposition conditions must be significantly lower in the case of Au and U. (Authors' abstract; references deleted)

BOIRON, M.C., CATHELINEAU, M., DUBESSY, J. and BASTOUL, A., 1988, Contrasted behavior of Au and U in French Hercynian granites at the hydrothermal stage: The role of fO_2 and pH: Rendiconti Della Soc. Italiana Di Min. & Petrol., v. 43-2, p. 485-498

The French part of the Hercynian belt in Europe is an important metallogenic province for Au and U. Most of the deposits were discovered in the vicinity of major shear zones, but are located either inside granitic rocks or in the surrounding metamorphic rocks. In spite of numerous similarities (age, presence of peraluminous granites, fluid circulation related to the late Hercynian activity), location of Au deposits in one hand, and U in other hand is distinct. This spatial distinction may be related to differences in the source rock location respective of the two metals. However, potential source rocks of both elements are either observed together in the vicinity of the deposits, or unknown. Thus, the hydrothermal stage was investigated as a key for the understanding of the contrasting behavior of U and Au.

In most of U deposits, pitchblende is associated with pyrite or hematite + pyrite in the veins whilst the stable mineral assemblage in the host rocks is: quartz-muscovite-feldspar-hematite. Fluids are considered to be mostly aqueous, low salinity, with a relatively low CO_2 content. fO_2 is high and higher than that fixed by the hematite-pyrite-magnetite triple point. pH is probably neutral.

In Au (As, Sb) deposits, two types of fluids may be distinguished: a) high T (300-400°C) fluids which are in some cases aqueous but more frequently belong to the CO_2-H_2O-CH_4 system; b) lower T fluids (150-250°C) which are dominantly aqueous and of low salinity. In most cases, strong K-mica alteration occurred which indicates a strong disequilibrium between fluids and host rocks and a rather low pH. fO_2 was low and probably around than that fixed by the Ni-NiO buffer.

Considering the experimental data on U and Au solubility and metal species in fluids, it is clear that under the above mentioned conditions U and Au cannot be mobilized and deposited together. U transport especially requires higher fO_2 values than those which are necessary for an effective Au solubilization. On the contrary, pH under deposition conditions must be significantly lower in the case of Au than U. (Authors' abstract)

BOIRON, M.C., CATHELINEAU, M. and TRESCASES, J.J., 1987, Comparative geothermometry using the chemical compositions of clay minerals and fluid inclusion data: Case study of the fossil system of Villeranges (French Massif Central) (abst.): Bull. de Liaison de la Soc. franc. de Min. et de Crist., v. 110, no. 5, p. 96 (in French). Authors at Lab. de Pérol. de la Surface, 40 Av. du Recteur Pineau, 86022 Poitiers Cedex, France.

The simultaneous utilization of several geothermometric techniques, more specifically the variations of the chemical composition of clay minerals and the study of fluid inclusions, has made it possible to work out the thermal history of a fossilized hydrothermal area: the Visean volcano-sedimentary basin of Villeranges located in the north-western part of the French Massif Central. Three stages can be recognized:

1) An early fluid circulation results in a regional diffused and selective alteration characterized in particular by the chloritization of the ferromagnesian minerals. These chlorites are characterized by a strong substitution of Si by Al (1.15-1.30) in the tetrahedral site. According to the geothermometer of Cathelineau and Nieva (1985), and Cathelineau (1987), their T of crystallization is probably high, at least 280 ± 20°C. These T are corroborated by the microthermometric study which yields minimum Tt in the range 280 ± 30°C.

2) A second fluid circulation event is limited to highly fractured areas where the mineral assemblage of the first stage is converted to K-mica + ankerite + quartz. Two generations of K-micas are present: the first one is composed of white micas altering the chlorites, and the second one of low charge illite altering largely the preexisting mineral phases (chlorites, white micas, feldspar). The use of the illite geothermometer (Cathelineau and Izquierdo, 1987) permits to estimate crystallization T between 250° and 270°C, and between 170° and 210°C, for the K-micas of the first generation, and the illites, respectively.

The last stage is contemporaneous with the crystallization of comb-textured quartz, that contains P fluid inclusions yielding Th in the range of 180 ± 20°C.

The simultaneous use of geothermometers based on clay minerals and fluid inclusions yields coherent results which allow us to define the thermal evolution of the fluid circulation stages in the basin under study. (Authors' abstract, translated by R. Moritz)

BOISSONNAS, J. and OMENETTO, P., eds., 1988, Mineral deposits within the European Community: Publ. Springer-Verlag, Berlin, 558 pp.

BONE, Y. and RUSSELL, N., 1988a, Palaeotemperatures in basin analysis - Direct correlation of vitrinite reflectivity with fluid inclusion microthermometry (abst.): Geol. Soc. Australia Abstract Series No. 21, p. 65. First author at Dept. Geol. & Geophys., Univ. Adelaide.

Palaeotemperatures are one of the most important parameters to be determined when petroleum exploration is the underlying reason for basin analysis. Vitrinite reflectance analysis is the most commonly used, rapid, method of assessing the thermal maturity of organic matter with respect to hydrocarbon generation. Currently, palaeotemperatures are estimated by comparing theoretical vitrinite reflectance values, calculated from subsidence rate and geothermal gradient modelling of a petroleum well, with the observed vitrinite reflectance values for the well. This paper reports the direct correlation of vitrinite reflectivity, determined by microscope photometry, and fluid inclusion Th, determined by microthermometry, for samples from a comprehensive suite of petroleum exploration wells in the Cooper Basin, South Australia.

The microthermometry was confined to very small (1-5 μm) fluid inclusions contained within silica overgrowths developed on detrital quartz grains present in siliciclastic sedimentary rocks. The T measured are in the range associated with hydrocarbon generation, expulsion and migration. Many of these inclusions contain fluids that are autofluorescent under excitation by ultraviolet or blue light, suggesting the presence of hydrocarbons. The Th values were plotted against vitrinite reflectance values, obtained, wherever possible, from organic matter within the same, or an adjacent core sample. The resultant plot permits a real T value to be assigned to a given vitrinite reflectance value, i.e., vitrinite reflectivity can be regarded as a true palaeothermometer. Conversely, in the absence of indigenous vitrinite, the Th of fluid inclusions within diagenetic overgrowths, or cements, can be used as a minimum basin T indicator at the particular site and as a guide to the thermal maturation of nearby organic matter. For comparative purposes microthermometric determinations were carried out on P fluid inclusions within the detrital quartz grains. These inclusions usually gave Th in excess of 300°C, indicating a probable igneous or metamorphic provenance.

It is planned to extend this study to other basins, in particular to basins that also contain carbonate rocks, e.g., Canning Basin. It is also planned to expand the fluid inclusion microthermometry facet of the study to include detailed analyses of the contained fluids, and, by the use of cathodoluminescence, to assign the individual fluid inclusions to a sequential fluid event, i.e., cement stratigraphy, thus leading to the construction of a comprehensive history of the basin. (Authors' abstract)

BONE, Y. and RUSSELL, N.J., 1988b, Correlation of vitrinite reflectivity with fluid inclusion microthermometry: Assessment of the technique in the Cooper/Eromanga basins, South Australia: Australian J. Earth Sci., v. 35, p. 567-570. First author at Dept. Geol. & Geophys., Univ. Adelaide, GPO Box 498, Adelaide, SA 5001, Australia.

For abstract, see previous item. (E.R.)

BOS, Ariejan, DUIT, Willem, van der EERDEN, A.M.J. and JANSEN, J.B.H., 1988, Nitrogen storage in biotite: An experimental study of the ammonium and potassium partitioning between 1M-phlogopite and vapor at 2 kb: Geochimica Cosmo. Acta, v. 52, p. 1275-1283. First author at Dept. Chem. Geol., Inst. Earth Sci., Univ. Utrecht, P.O. Box 80.021, 3508 TA Utrecht, The Netherlands.

The NH_4^+ and K^+ distribution between phlogopite and a chloride vapor phase was investigated at 550°C and 2000 bars. The extrapolation to low NH_4^+ concentrations in natural rock systems may provide estimates of NH_4^+ concentrations for metamorphic fluids in equilibrium with NH_4^+-bearing minerals. The assumption that Rb^+ behaves similarly to NH_4^+ allows a rough estimate of the distribution coefficients of NH_4^+ in other minerals. Semiquantitative modelling based on the derived distribution coefficients of NH_4^+ and Rb^+ may elucidate fluid/rock equilibria during closed system behavior. The release of nitrogen by breakdown of NH_4-bearing biotite during prograde or retrograde processes in metamorphic rocks may explain the presence of N_2-gas in fluid inclusions. (From the authors' abstract by E.R.)

BOTTINGA, Y. and JAVOY, M., 1988a, Nucleation, growth and chemical evolution of gas bubbles in MORB (abst.): EOS, v. 69, p. 1465. Authors at Inst. Physique du Globe, 75252 Paris, France.

The high surface energy of basalt has as consequence that CO_2 bubble nucleation requires a supersaturation varying from a factor 1.5 at P >5 Kb to 5 at P <0.2 Kb. Due to the relatively great abundance and small solubility of CO_2 in MORB, bubbles formed at depth will be the result of CO_2 supersaturation. These can escape from the ascending basalt if they are large enough, i.e., larger than about 0.07 mm in diameter, to have a Stokes' velocity of more than 2 mm/hr. For this to happen the nucleation number density should be less than 10^6 nuclei/cm^3. If the MORB, formed at about 60 km depth, is saturated with CO_2 when it is generated by partial melting, bubble nucleation will take place at about 40 km depth, because of the required supersaturation factor of 1.5. Initial CO_2 saturation in MORB is suggested by the carbon isotopic compositional variations, by the near constancy of the $^3He/CO_2$ ratio and by the He budget of the mantle. When the bubble number density is greater than 10^5, the bubble diameter will be too small for significant bubble movement with respect to the ascending magma to occur at P greater than 200 bars. This implies that no degassing takes place under these conditions. Also at P = 200 bars the vesicularity will be 30%. Moreover more than 95% of the CO_2, more than 90% of the He and Ar, and nearly 17% of the total H_2O will be in CO_2 bubbles. However the basalt is still not water saturated, therefore no H_2O bubbles have been formed yet.

Numerical analysis of the growth of multicomponent stationary and nonstationary gas bubbles gave these results. The occurrence of bubble nucleation was thermodynamically investigated. Gas imperfection was taken into account. (Authors' abstract)

BOTTINGA, Y. and JAVOY, M., 1988b Nucleation and growth of CO_2 bubbles in MORB (abst.): Chem. Geol., v. 70, p. 36. Authors at I.P.G.P., 4 place Jussieu, 75252 Paris Cedex 05, France.

We will discuss the theoretical aspects of CO_2 escape from the mantle. Of the major gases dissolved in MORB CO_2 has the smallest solubility, consequently it forms the first bubble in rising MORB. The fairly large surface energy of basalt melts is the cause of a large degree of supersaturation needed before homogeneous nucleation occurs. But the size and configurational distributions of bubbles in MORB suggest strongly that nucleation is homogeneous, contrary to popular belief. Calculation of the free energy of CO_2 bubble nucleus formation shows that the CO_2 concentration should be at least three times greater than the equilibrium concentration for nucleation to take place. This is compatible with the known CO_2 solubility and the observed concentrations in MORB. Initially the small bubble are stationary, they grow by diffusion and buoyancy causes them to move in the melt. From then onwards equilibrium between the melt and bubble is unattainable. Because of the large degree of supersaturation required for nucleation, solubility determinations based on the appearance of bubbles are usually nonvalid, erupting MORB will be supersaturated in CO_2, and the presence of different generations of bubbles becomes understandable. Most of the rare gases in MORB are in CO_2 bubbles. According to chemical and isotopic evidence MORB starts to exsolve CO_2, when it contains between 5000 and 13000 ppm CO_2. Hence MORB is already saturated with CO_2 when it is formed by partial melting. Hence the initial CO_2 content of MORB is restricted by a solubility limit. The ^3He concentration in MORB should be a simple function of the degree of partial melting if ^3He is uniformly distributed in the mantle. With the great majority of ^3He being in CO_2 bubbles, it is to be anticipated the $^3He/CO_2$ ratio should be approximately constant in MORB as has been repeatedly observed. (Authors' abstract)

BOTTRELL, S.H., CARR, L.P. and DUBESSY, J., 1988, A nitrogen-rich metamorphic fluid and coexisting minerals in slates from North Wales: Mineral. Mag., v. 52, p. 451-457. First author at Dept. Earth Sci., Univ. Leeds, Leeds LS2 9JT, UK.

Volatile species analysis of fluid inclusions in metamorphic quartz veins from the Llanbedr Formation, North Wales, show nitrogen to be an important component. Microthermometric and Laser Raman analysis indicates that the N_2 is resident in a generation of very N_2-rich inclusions and demonstrates the presence of both N_2-rich and aqueous fluids during metamorphism of the Llanbedr Formation. N_2-rich fluids do not appear to have been present in adjacent lithologies. Isotopic analysis of N_2 in fluid inclusions in the slates indicates that the N_2 in the slates (thought to be present as NH_4^+ substituting for K^+ in muscovite and for Na^+ in albite) was probably originally derived from organic matter in the sediment and subsequently released to the fluid phase during metamorphism.

Mineral-fluid and fluid-phase equilibrium calculations show that the mineral assemblage in the slates could be in equilibrium with either N_2-rich or aqueous fluid depending on redox conditions. The N_2-rich and aqueous fluids in the veins could, therefore, have been trapped at different times under different conditions, though their coexistence as immiscible fluids is a possibility. (Authors' abstract)

BOTTRELL, S.H., SHEPHERD, T.J., YARDLEY, W.D. and DUBESSY, J., 1988, A fluid inclusion model for the genesis of the ores of the Dolgellau Gold Belt, North Wales: J. Geol. Soc. London, v. 145, p. 139-145.

This is the full paper for two abstracts in Fluid Inclusion Research, v. 19, 1986, p. 55-56. (E.R.)

BOTTRELL, S.H. and SPIRO, B., 1988, A stable isotope study of black shale-hosted mineralization in the Dolgellau gold belt, North Wales: J. Soc. London, v. 145, Part 6, p. 941-949.

See previous item. (E.R.)

BOTTRELL, S.H., and YARDLEY, B.W.D., 1988, The composition of a primary granite-derived ore fluid from S.W. England, determined by fluid inclusion analysis: Geochim. Cosmo. Acta. v.52, p.585-588. Authors at Dept. of Earth Sciences, Univ. of Leeds, Leeds LS2 9JT, U.K.

Electrolyte concentration in aqueous fluid inclusions in quartz from a high T hydrothermal rock have been measured for 15 elements by an improved crush-leach procedure. The primary hydrothermal fluid was dominated by NaCl and has been shown by previous studies to have been about 3 m with respect to Cl. On this basis the molar concentrations include Fe=0.21, Mn=0.06 and Zn=0.02, and the fluid is interpreted as parental to some of the S.W. England ore bodies. (Authors' abstract)

BOTTRELL, S.H., YARDLEY, Bruce and BUCKLEY, Frank, 1988, A modified crush-leach method for the analysis of fluid inclusion electrolytes: Bull. Minéral., v. 111, p. 279-290. Authors at Dept. Earth Sci., Univ. Leeds, Leeds, LS2 9JT, UK.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 53-44. (H.E.B.)

BOUDREAU, A.E., 1988, Investigations of the Stillwater complex. IV. The role of volatiles in the petrogenesis of the J-M reef, Minneapolis adit section: Canadian Mineral., v.26, p.193-208. Author at Dept. of Geol. Sci., AJ-20, Univ. of Washington, Seattle, WA 98195.

Extensive activity of Cl-rich aqueous fluids in the genesis of the olivine-rich rocks of olivine-bearing zone I(OBZI) of the Stillwater Complex, in Montana, host of the PGE-bearing J-M Reef, is evident in the relative abundance of Cl-rich hydrous phases and the common occurrence of pegmatitic textures. Polymineralic inclusions of hydrous and anhydrous minerals in chromite and apatite are interpreted to have crystallized from trapped volatile-rich melt. The presence of anorthositic zones around layered and podiform segregations of olivine-rich rocks are interpreted as metasomatic zones because they are commonly monomineralic, have sharp contacts with neighboring rocks, and have separate mineral assemblages that are not in equilibrium. A Cl-rich, PGE-bearing volatile fluid migrating through a largely solidified cumulate sequence can be redissolved in stratigraphically higher, hotter intercumulus melt that is vapor-undersaturated. This would localize volatile enrichment to a particular zone and result in partial melting of the cumulates. Modal and textural data are consistent with a model in which progressive interaction of a (gabbro)norite+interstitial melt protolith with volatile fluid lead to the following sequence of reactions: olivine was produced by incongruent melting of pyroxene, and incomplete melting of plagioclase produced round, reversed-zoned grains. Chromium, liberated during the destruction of pyroxene, was precipitated as chrome spinel. With increasing fluid/rock ratio, phlogopite and other hydrous phases were eventually precipitated, whereas chrome spinel became unstable and was reprecipitated outward of the fluid-rich areas. This reaction sequence was accompanied by a decrease in the fugacities of both oxygen and sulfur. (Author's abstract)

BOUHLEL, S., FORTUNÉ, J.-P., GUILHAUMOU, N. and TOURAY, J.-C., 1988, The F-Ba stratiform mineralizations of Hammam Zriba, Jebel Guébli (northern Tunisia): Fluid inclusions and a genetic model: Mineral. Deposita, v. 23, p. 166-173 (in French; English abstract). First author at Lab. Ressources Min., Fac. Sci. de Tunis, Campus Univ., 1060 Tunis, Tunisia.

In the H. Zriba-J. Guebli mine (5 millions tons of ore with 15%-35% CaF_2) the ore deposits are mostly stratiform bodies hosted by lower-Campanian clay-carbonate sediments with significant phosphate contents. Four successive ore formations are apparently fluorite-free and either quartz-rich or barite-rich with minor amounts of sulfides. The "fluorine rubannée" (formation F_1) is the main economic ore. Three major fluid inclusions types have been observed in fluorite: (1) abundant aqueous inclusions, (2) rare gas inclusions, and (3) usually yellow oil-bearing inclusions with intense UV fluorescence. In microthermometric investigations on primary aqueous inclusions a general increase in the Th from about 100°C to 130°C in fluorite F_1 up to 150°-185°C in fluorite F_3 with simultaneous increase in salinity was observed. Finally, fluorite crystallized epigenetically in formation-water-type brines; the last geodic filling by fluorite F_3 is tentatively related to Miocene hydrothermal circulation. (Authors' abstract)

BOULLIER, A.M., MICHOT, G. and PECHER, A., 1987, Diffusion and/or plastic deformation around fluid inclusions in synthetic quartz (abst.), in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 756. First author at Centre de Recherches Pétrogr. & Géochim., B.P. 20, 54501 Vandoeuvre-lès-Nancy, France.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 44-45. (E.R.)

BOULLIER, A.M., PECHER, A. and FRANCE-LANORD, C., 1988, Fluid inclusions in the M.C.T. pile in central Nepal: Himalayan-Karakoram-Tibet workshop meeting, Lausanne (Switzerland), October [1988], 4 pp.

Fluid inclusions may give information on the nature of the fluids which percolated through rocks, on their origin and on the (P, T, t) path of the pile. Previous studies on the M.C.T. pile in central Nepal showed that: 1) below the thrust plane, fluids are mainly $H_2O + CO_2$, CO_2 increasing towards the M.C.T. (A. Pêcher, 1979); 2) based on isotopic data (C, H, O) on fluids, minerals and bulk rocks, important fluid circulation took place below the M.C.T. and CO_2 was derived both from oxidation of graphite in graphitic schists and from decarbonation of calcareous rocks below the outcropping Midlands (C. France-Lanord, 1987); and 3) densities of fluid inclusions indicate lower P than expected from the metamorphic mineral assemblages. This fact is attributed to post-trapping reequilibration during uplift (A. Pêcher, 1979).

We studied fluid inclusions in quartz pods of the Bhuri Gandaki valley in 200 μm thick sections, especially from a textural point of view. The following facts were established: 1) the observations by Pêcher (1979) on the nature of the fluids across the entire pile are confirmed; 2) saline fluids become abundant in the upper part of Formation I (above the M.C.T.); 3) fluids are localized in healed microcracks (with different degrees of healing), or in isolated fluid inclusions, or in grain boundaries; 4) healed microcracks are mainly oriented at high angels to the foliation and lineation and are sometimes subsequently reworked by plastic deformation; and 5) decrepitation structures have been observed; we show that they are induced either by plastic deformation or by P decrease. All these observations indicate that fluid inclusions give information on the fluids present during the history of the Pile and not only during the latest stages. They provide useful thermal and textural constraints relative to the (P, T, t, ε) path of the M.C.T. pile, for example for the chronology of plastic strain and uplift. (Authors' abstract)

BOUTALEB, M., 1988, Reconstruction of the tectonometamorphic, magmatic and hydrothermal evolutions in the tin-tungsten bearing area of Walmes (Central Morocco) and its metallogenic significance: Ph.D. dissertation, Inst. Nat'l. Polytech. de Lorraine, 269 pp (+ appendix volume; 105 p.) (in French).

The intra- and peri-batholithic quartz-cassiterite/quartz-wolframite ore deposits at Walmes are associated with the multi-stage emplacement of the Walmes granitic pluton, which includes, successively emplaced: biotite El Karit granite (EK); main two-mica granite (p); two-mica granite porphyry (π); and muscovite granite (mu). The EK and p granites are syntectonically emplaced in a very low grade cover of Cambro-Ordovician sandstones and pelites. Mineralogical and fluid inclusion data constrain the lithostatic P at this stage at ~2 kb (0.2 GPa). The pluton is of alumino-potassic type. All granites were initially biotite granites. Subsolidus development of muscovite occurs in one or several stages, according to the timing of emplacement of the concerned granite. Muscovitization events are related to hydrothermal circulation responsible for ore deposition.

Four mineralizing stages are recognized: 1) peri-batholithic El Karit muscovite-cassiterite-beryl event contemporaneous with the end of p emplacement; 2) intra-batholithic Assouel cassiterite, associated with π emplacement; 3) intra-batholithic Tarmilat cassiterite, possibly associated with late mu emplacement; 4) intra- and peri-batholithic Tarmilat/Zguit wolframite. Fluid inclusions record a continuous decrease in lithostatic P, from ~1.5 kb (0.15 GPa) at the El Karit stage down to ~1 kb (0.1 GPa) at the Tarmilat/Zguit stage. They also give evidence for a cyclic thermal evolution, characterized by a succession of reheating and subsequent T decrease, probably related to the successive granite intrusions. Elevated T (550°-500°C) are recorded for the beginning of the earlier El Karit and Assouel stages. Cassiterite deposition typically took place at 450°-400°C. Hydrothermal fluids are of low salinity from the beginning. There is no evidence for the contribution of a magmatic fluid. Early fluids involved in the El Karit circulation have a significant content of volatiles (C-O-H-N fluids) and are evidently of metamorphic derivation; their dilution by cooler purely aqueous fluid is clearly responsible for cassiterite deposition. The same sequence of events is observed at Assouel. (Author's abstract)

Note: See also 1988 Ph.D. by Bennani, this volume. (E.R.)

BOUZENOUNE, A., 1988, Fluid inclusion studies in the late stage quartz of the polymetallic ore veins at Saf-Saf (Edough Massif,NE Algeria): DEA dissertation, Centre de Recherches Pétrogr. & Géochim., 48 pp. (in French).

The Saf-Saf polymetallic (Fe-Zn-Cu-Pb) ore veins are part of a set of similar mineralizations of Late Tertiary age occurring in and around the Edough Massif. They are notable for the presence, at the late mineralization stages, of the stibnite-arsenopyrite (Sb-bearing) assemblage, while only arsenopyrite (Sb-bearing) is observed in the other vein systems. The Edough Massif is made up of a core of high grade gneisses, with a tectonic cover of Cretaceous and Tertiary flysch nappes. The whole pile is intruded by microgranite laccolitic bodies and rhyolite dikes of Late Tertiary (Langhian) age. The ore veins cross-cut the gneisses, flysch nappes and magmatic bodies.

Only late quartz contains fluid inclusions in the Saf-Saf veins. They record the late stages of main ore deposition (Q1, with minor sphalerite and chalcopyrite) as well as the latest, Sb-bearing, event (Q2, associated with Sb-arsenopyrite and stibnite). Q1 quartz record a progressive decrease in T, from 270°C to 200°C. Two kinds of fluids are involved: low saline A fluids ($\leq$0.7 wt % eq NaCl), always present, of probable meteoric derivation; more saline B fluids ($\leq$5 wt % eq NaCl), sporadically present, exhibiting isothermal mixing trends with the A fluids. These mixing events are responsible for the minor Cu and Zn deposition. Q2 quartz record a strong reheating of the system, up to ~300°C, followed by a final cooling. Again, isothermal mixing of A-type and B-type fluids is correlated with As-Sb depositions. The two thermal cycles thus evidenced are apparently correlated to the successive intrusion of micrograntes and rhyolites in the Edough Massif. (Author's abstract)

BOWERS, T.S., CAMPBELL, A.C., MEASURES, C.I., SPIVACK, A.J., KHADEM, Mitra and EDMOND, J.M., 1988, Chemical controls on the composition of vent fluids at 13°-11°N and 21°N, East Pacific Rise: J. of Geoph. Res., v.93, n.B5, P.4522-4536.

BOWMAN, J.R., BROMLEY, K.S. and COOK, S.J., 1988, Disequilibrium ^{18}O exchange resulting from fluid-rock interaction during development of the Corral Canyon shear zone, Utah (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. A45. Authors at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112.

The Corral Canyon shear zone is one of several denudation faults resulting from Great Basin extension which cut Tertiary (16 m.y.) granite on the west flank of the Mineral Mountains. The initial δ^{18}O values of unaltered granite are: whole rock (WR), +7.6, quartz (Qz), +9.6, K-feldspar (Kfs), +7.5. Within the shear zone, ^{18}O depletion accompanies progressive hydrothermal alteration and cataclasis, with δ^{18}O values decreasing to -2.8 (WR) and -3.5 (Kfs). Fluid inclusion studies indicate that hydrothermal alteration, shearing, and isotopic exchange took place in the T range 200-300°C. As alteration and shearing progress, Kfs undergoes preferential ^{18}O depletion relative to Qz and is out of exchange equilibrium with Qz through most of the alteration sequence. However in the most extensively sheared and altered samples, Qz approaches exchange equilibrium with Kfs at the estimated T of hydrothermal alteration.

The kinetic and mass conservation equations formulated by Criss et al. (1987), together with the kinetic rate data of Cole and Ohmoto (1986), have been used to compute ^{18}O exchange trajectories for Qz and Kfs as a function of time, surface area, T, and fluid infiltration rates. In order to reproduce the observed trends in δ^{18}O values of Qz and Kfs at 250°C, either the rate of fluid infiltration must vary (between 3×10^{-8} sec^{-1} and 2×10^{-10} sec^{-1}), or the δ^{18}O values of the fluid infiltrating into the shear zone must vary by at least 4‰. If T of alteration/exchange were as high as 300°C, the calculated exchange time necessary to reequilibrate the initial δ^{18}O values of the Qz could be as short as 4000 years. However this exchange time may be much less than the structural life of the shear zone, if fluid infiltration and shearing is discontinuous. (Authors' abstract)

BOWMAN, J.R. and COOK, S.J., 1988, Influence of pathlengths of isotopic exchange in hydrothermal flow systems on calculated water/rock ratios: Examples from the Bingham Canyon porphyry copper system and the Alta Stock thermal aureole, Utah (abst.): EOS, v.69, p.464.

BOWMAN, M.W. and GOLDSTEIN, R.H., 1988 - See Appendix

BOYD, S.R., MATTEY, D.P., PILLINGER, C.T., MILLEDGE, H.J., MENDELSSOHN, M. and SEAL, M., 1987, Multiple growth events during diamond genesis: An integrated study of carbon and nitrogen isotopes and nitrogen aggregation state in coated stones: Earth Planet. Sci. Lett., v. 86, p. 341-353.

BOYD, S.R. and PILLINGER, C.T., 1988, Carbon and nitrogen isotopes in the mantle (abst.): Chem. Geol., v. 70, p. 46. Authors at Dept. Earth Sci., Open Univ., Walton Hall, Milton Keynes, UK.

$\delta^{13}C$ and $\delta^{15}N$ measurements have been performed on coated and octahedral (+ modified forms) diamonds from Australia, Africa, Siberia and N. America. Amongst the octahedral diamonds two broad groups can be distinguished. Group O_1 diamonds (e.g., Finsch, South Africa) have $\delta^{13}C$ values between -3 and -7‰ (similar to most other upper mantle samples) and contain nitrogen generally depleted in ^{15}N relative to AIR; $\delta^{15}N$ ca. -5‰ (range +5 to -16‰). Group O_2 diamonds (e.g., Argyle, W. Australia) have variable $\delta^{13}C$ values (-2 to -21‰) and contain N generally enriched in ^{15}N relative to AIR; ca. +5‰ (range -5 to +16‰).

The coatings on diamonds from Sierra Leone, Siberia, Angola, Botswana and Zaire have a restricted range in isotopic composition ($\delta^{13}C$ -5 to -7.5‰, $\delta^{15}N$ -2 to -8‰). Both group O_1 and O_2 diamonds were present as cores within these samples. The coats of coated diamonds have been interpreted as being phenocrysts. Their isotopic uniformity on a regional scale suggests the existence of a fairly homogeneous C and N reservoir underlying the continental lithosphere which supplies the volatiles associated with kimberlite eruptions. The Siberian pipe (Udachnaya) is of mid-Palaeozoic age which implies that, by this time, the extreme carbon isotope heterogeneity within the mantle (+3 to -35‰) was restricted to the continental lithosphere.

The isotopic characteristics of the coats are similar to the O_1 diamonds. Since diamonds from Finsch and Premier (both O_1) have been dated at 3.3 Ga and 1.2 Ga respectively there appears to have been little change in the $\delta^{13}C$ and $\delta^{15}N$ value of the asthenospheric reservoir since the mid-Archean.

The origin of the isotopic characteristics of the group O_2 diamonds is uncertain. The observation that they tend to occur in diatremes located close to craton margins (or off the craton in the case of Argyle) indicates that they are associated with young rather than older lithosphere which argues against the primordial heterogeneity model of Deines et al. (Authors' abstract)

BOYLE, R.W., ed., Gold: History and genesis of deposits: Van Nostrand, Reinhold, 1987, 676 pp.

BRADFORD, J.A., 1988, Geology and genesis of the Midway silver-lead-zinc deposit, north-central British Columbia: MS thesis, The Univ. British Columbia.

The Midway Ag-Pb-Zn manto deposit is hosted in Middle Devonian McDame Group limestones. ... Two intrusive suites, of mid-Cretaceous (100 Ma) and Late Cretaceous (70 Ma) ages, are documented by K-Ar dating. The Late Cretaceous episode is evidenced by large sericite-pyrite alteration zones southeast of Midway, but only a few felsic porphyry dikes are exposed at current erosion levels.

High angle faults in the Tootsee River fault zone confined intrusion driven hydrothermal fluid migration up plunge from an intrusive center about 2 km southeast of Midway. Fluids were ponded in a southeasterly plunging antiformal trap, and massive sulphides deposited in zones of pre-existing karst breccia porosity beneath a relatively impermeable shale cap. Fe- and Cu-rich pyrrhotitic assemblages occur at greater depth toward the intrusive center, with sulphosalt-rich pyritic assemblages at shallower depths to the north.

Immiscible aqueous-carbonic liquid and vapor were trapped in quartz deposited with sulphides at 300-340°C. Later lower T inclusions record the progressive loss of CH_4 and CO_2 from the system. Salinities were about 7-10 wt % NaCl eq. Sulphur isotopes of sulphides span a narrow range, indicating a well mixed reservoir and H_2S dominated environment. Both sedimentary and igneous sources are indicated. Oxygen isotopes of carbonates demonstrate large ^{18}O depletions due to extensive meteoric water interaction. In a regional context (Rancheria Ag district), Midway Pb isotopes suggest mixing of upper crustal Pb from country rocks with intrusion derived lower crustal Pb. Cassiar Terrane epigenetic deposits are distinguished from epigenetic deposits of Slide Mountain Terrane, which have significant mantle Pb, consistent with derivation from oceanic and arc host rock assemblages. (From the author's abstract by E.R.)

BRANDANI, Vincenzo, DEL RE, Giovanni and DI GIACOMO, Gabriele, 1988, Thermodynamics of aqueous solutions of boric acid: J. Solution Chem., v. 17, no. 5, p. 429-434.

BRANTLEY, S.L., 1988, Effects of fluid chemistry on microcrack healing in quartz (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A43-A44. Author at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802.

Sequential healing of microcracks in quartz reveals the rates and mechanisms of the healing process. Using the model of Evans and Charles (1977) and assuming an Arrhenius dependence for crack healing rates, the activation energy observed for healing between 400° and 600°C (80 KJ/mol ± 26 KJ/mol) suggests that dissolution or precipitation is the rate-limiting step of healing. Preliminary results have also shown that healing rates increase with increasing water P. We are investigating the effects of fluid chemistry (ionic strength, XCO_2) on the healing process. Preliminary results have not revealed any measurable effect of NaCl concentration on healing rates, although we hypothesize that crack healing, like stress corrosion and fluid wetting behavior, should show a NaCl concentration dependence. We also predict slower healing rates with increasing XCO_2.

Since the permeability of fractured media is strongly related to fracture aperture, most fluid percolation through rocks occurs through large-scale fractures. Such large fractures are connected to finer porosity consisting of interconnected pores and microcracks. Ths fine-scale porosity must account for the chemical and isotopic equilibration of the bulk of the rock, since the larger fractures segregate the flowing fluids from interacting with the rock mass. Our results suggest that the two scales of porosity have vastly different lifetimes: fractures transport most of the fluid volume and seal up relatively slowly, while microcracks allow penetration of fluid into the rock mass but remain open for geologically short periods of time. (Author's abstract)

BRATHWAITE, R.L., CHRISTIE, A.B. and FRY, B.M., 1987, Hydrothermal breccias and argillic alteration at Gladstone Hill: A high level (Hot Springs) zone of the Waihi gold-silver hydrothermal system (abst.): Geol. Soc. N. Zealand Misc. Pub. 37A, Programme and Abstracts 1987 Conf. Geol. Soc. N. Zealand (unpaginated). Authors at New Zealand Geol. Survey, DSIR, PO Box 30368, Lower Hutt.

Hydrothermal breccias and quartz veins occur at Gladstone Hill, 1.5 km east of the deeper level (emplaced at 300-900 m below paleosurface) Martha Hill part of the Waihi epithermal quartz vein system. Both hills are composed of Late Miocene Coromandel Group andesites which are overlain by post-mineralization dacite and ignimbrite of Pliocene to early Quaternary age.

At Gladstone Hill, diamond drilling has defined a hydrothermal breccia zone containing local high grade Au-Ag values (Gold Resources Ltd. Prospectus 1987). Logging of drill core together with petrographic, XRD and fluid inclusion studies have show a complex pattern of hydrothermal alteration and fracture filling. Banded quartz-pyrite veins, associated with quartz + chlorite + calcite + adularia + pyrite propylitic alteration, represent an early event which correlates with second stage vein filling in the upper part of the Martha Lode. The propylitic alteration is overprinted by illite + pyrite ± kaolinite ± smectite argillic alteration associated with the formation of the hydrothermal breccia zone. The breccias are composed of clasts of vein quartz and illite-altered andesite in a variety of matrices: chalcedonic quartz + pyrite, chlorite + kaolinite + pyrite, illite + smectite + kaolinite, smectite + pyrite, or kaolinite + illite + quartz + pyrite. The breccias and associated argillic alteration were probably formed relatively near the surface (170-300 m below paleosurface) in a "Hot-Springs" type epithermal system featuring repeated silica sealing, gas-driven brecciation, and argillic alteration from acid-sulphate steam condensates. (Authors' abstract)

BRATUS', M.D., TATARINTSEV, V.I. and SAKHRO, B.E., 1987, Fluid-inclusion compositions in chilled particles from explosive ring structures and kimberlite pipes: Geokhimiya, no. 11, 1987, p. 1563-1568 (in Russian; translated in Geochem. Int'l., v. 25, no. 6, p. 50-55, 1988). First author at Inst. Fossil-Fuel Geo. & Geochem., Ukrainian Acad. Sci., L'vov.

Mass spectrometry has been applied to the study of the gas components in glass spherules close in composition to melilite and to ash and magnetic products consisting of chilled particles from explosion structures in the Ukrainian shield and from kimberlites. The predominant gas component in the inclusions is nitrogen. Carbon dioxide and methane together account for not more than 20 vol.%. The CO_2/CH_4 ratio is correlated with the degree of oxidation of the iron. The gas inclusions contain water vapor. (Authors' abstract)

Twenty-two analyses for CO_2, N_2, CH_4, Ar and H_2O are presented. (E.R.)

BRAY, C.J., SPOONER, E.T.C., and LONGSTAFFE, F.J., 1988, Unconformity-related uranium mineralization, McClean deposits, North Saskatchewan, Canada: Hydrogen and oxygen isotope geochemistry: Canadian Mineralogist, v.26, p.249-268. First author at Dept. of Geol., Univ. of Toronto, Toronto, Ontario, M5S 1A1.

Gives original (?) inclusion Th data (p.258) for quartz and dolomite from Rabbit Lake and overgrowths on clastic quartz from Rumple Lake (≈160-220°C), with Na-Ca-Cl brines of 30 eq. wt. % as the ore fluid. The McClean deposit gave no usable inclusions. (E.R.)

BREDEHOEFT, J.D., 1988, How fast and how much WIPP brine will reach waste containers?: EOS, v.69, p.121, Author at U.S. Geol. Survey, Menlo Park, CA.

A discussion of the permeability and brine movement in the salt formations at the WIPP site in Carlsbad, N.M. (See also discussion by Spiegel and Anderson, EOS, v.69, no. 22, p.125 and 628, 1988) (E.R.).

BRENAN, J.M. and WATSON, E.B., 1988a Wetting characteristics of CO_2-H_2O fluids coexisting with olivine as a function of P and T (abst.): EOS, v.69, p.482.

BRENAN, J.M. and WATSON, E.B., 1988b Wetting properties of possible mantle metasomatic fluids (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 32. Authors at Dept. Geol., Rensselaer Polytech. Inst., Troy, NY 12180, USA.

The equilibrium distribution of some possible metasomatic fluids in the upper mantle has been determined by experimentally characterizing the dihedral angle, Θ (the angle formed by two intersecting walls of a pore with two solid grains), for CO_2-H_2O fluids and carbonate melts in synthetic dunite. For CO_2-H_2O fluids, results of experiments at 1000°C-1150°C, 1.0 GPa indicate Θ varies from ~65° at $X(H_2O) = 1$ to ~90° at $X(H_2O) = 0.14$. Experiments with H_2O plus dissolved salts (CaF_2, NaCl, Na_2CO_3) given Θ ~65° and indicate these solutes have no effect on the wetting aspects of hydrous fluid. Na and K carbonate melts equilibrated at 1250°C, 1.0 GPa have Θ ~25°; addition of 1-10 wt% CO_2 or 10 wt% H_2O has no discernible effect on this value. An experiment at 1350°C, 1.0 GPa involving hydrous Ca carbonate melt gives Θ ~30°; the same value is obtained for dry Ca carbonate melt at 1400°C, 3.0 GPa.

For Θ >60°, fluid in a rock will occur as isolated pockets dominantly at grain corners and will lack 3-dimensional connectivity. Results indicate that CO_2-H_2O fluids will occur as isolated pores in a static upper mantle and therefore hydrofracturing is the likely mechanism for fluid transport. Carbonate melts, with low values of Θ, will be interconnected and may thus allow fluid transport by porous flow or surface tension driven infiltration. Porous flow separation velocities >10 mm/yr [McKenzie, EPSL 74:81] and melt infiltration "diffusivities" $\sim10^{-2}$ cm^2/s [Stevenson, GRL 13:1149] are predicted for carbonate melt fractions as low as 0.1%. Such high predicted mobilities, coupled with 1) the invariant nature of Θ for carbonate melts w/ or w/o added volatiles and 2) the elevated concentrations of typically dispersed elements in natural carbonatites suggests that such melts can be effective transport media for trace elements and volatiles and thus potentially important mantle metasomatic agents. (Authors' abstract)

BRIGO, L., DULSKI, P., MÖLLER, P., SCHNEIDER, H.-J. and WOLTER, R., 1988, Strata-bound mineralizations in the Carnic Alps/Italy, in Mineral deposits within the European community, J. Boissonnas and P. Omenetto, eds.: Publ. Springer-Verlag, Berlin, p. 485-498. First author at Inst. Mineral. dell'Univ. di Ferrara, Corso Ercole 1° d'Este, 32, I-44100 Ferrara, Italy.

The strata-bound mineralizations of the Palaeocarnic Alps/Italy are characterized by a zonation of parageneses: predominating Hg-Cu sulphides in the west, ZnS in the center, barite and fluorite in the east.

Fluid inclusions in fluorite and barite are, in general, very small and mainly single phase. Their freezing T are between -13° to -15°C, indicating a salinity of 18 to 19 wt% NaCl eq.

The few two-phase inclusions show Th between 50° and 104°C. Their freezing T are in the range of -10.8° to -18.8°C, indicating salinities of 14 to 23 wt% NaCl eq.

In one sample only, inclusions with high Th (170° to 230°C) were detected with freezing T, indicating 20 to 21 wt% NaCl eq. The frequent occurrence of very small (<0.5 μ) and single-phase inclusions indicates that the mineralization of fluorite and barite took place at low T. This could be the result of mobilization during diagenesis. (E.R.)

BROADHURST, C.L., DRAKE, M.J., HAGEE, B.E. and BERNATOWICZ, T.J., 1988, Solubilities and partitioning of noble gases in mineral/melt systems: Results for Ne, Ar, Kr, and Xe in anorthite, diopside, forsterite, and coexisting melt with implications for terrestrial planet atmospheric evolution (abst.): 51st Ann. Meeting of the Meteoritical Soc., Fayetteville, AR, July 18-22, 1988, Abstracts, p. M-8 (Lunar and Planetary Inst. Contrib. 665).

BROMAN, C., 1988, Fluids associated with the genesis of the Skellefte district massive sulfide deposits, Sweden: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 191-200. Author at Dept. Geol., Univ. Stockholm, S-10691 Stockholm, Sweden.

Fluid inclusion data indicate that the Skellefte district massive sulfide deposits were formed over a T range from 145-377°C at a seawater depth of at least 2.5 km. The ore-forming solutions were non-boiling Ca-Na-Cl fluids with an average salinity of 4 ± 2 wt.% NaCl eq., similar to seawater. The underlying Cu-rich stringers were deposited between 250-366°C from CO_2-bearing H_2O-rich fluids.

The ores have been affected by subsequent low-grade metamorphism involving three main types of fluids: (1) CO_2-rich, (2) hydrocarbon-rich (mainly CH_4), and (3) saline (28-32 wt.% $CaCl_2$ eq.) aqueous solutions. (Author's abstract)

See also Broman, 1986, Fluid Inclusion Research, v. 19, p. 63-64; v. 20, p. 52; and 1987, Fluid Inclusion Research, v. 20, p. 52. (E.R.)

BROOKINS, D.G., 1988, Eh-pH diagrams for geochemistry: Springer-Verlag, New York, 1988 (ISBN 0-387-18485-6).

BROWN, P.E., 1988, Fluid inclusions in Martian samples; clues to early crustal development and the hydrosphere: LPI Tech. Report 88-07, Workshop on Mars sample return science, p. 44-45.

Major questions about Mars that could be illuminated by examining fluid inclusions in Martian samples include (1) the nature, extent and timing of development (and decline) of the hydrosphere that existed on the planet, and (2) the evolution of the crust. Fluid inclusion analyses of appropriate samples (see below) could provide critical data to use in comparison with data derived from analogous terrestrial studies.

Solid rock samples returned from Mars could well contain a variety of inclusions that record information both from the time of the rocks formation as well as later events that have occurred to and around the sample. Magmatic rocks, either intrusive or extrusive, will contain now largely solid inclusions that represent the bulk(?) magma composition at various times in the crystallization of the sample. In basaltic compositions (low angle flank slopes; Olympus Mons?, Alba Patera?) olivine is the most propitious host mineral for magmatic inclusions; in more silicic compositions (steeper slopes; Elysium Mons?), quartz, if present, provides the best host for liquid/gas inclusions. In addition to melt inclusions, these same samples (especially the more silicic ones) are likely to contain trapped, largely fluid, inclusions that preserve the volatile phase present during the crystallization or cooling process. This volatile phase may have evolved directly from the magma during cooling, may be "groundwater" present a the site of magmatic activity and moved in response to thermal convection, or a combination of the two. [Lunar samples contain solid melt inclusions but no liquid inclusions, presumably reflecting the anhydrous nature of the melts and the lack of a hydrosphere during lunar development.] The presence of polar water- and carbon dioxide-containing "ice caps" on Mars as well as the abundant evidence for widespread liquid water early in the geologic history of Mars strongly suggest that appropriate samples will contain fluid inclusions. Radiometric age dating of the same samples would address the absolute timing of major (or minor) hydrothermal activity and could be extended to deal with the timing of surficial (or near surface) hydrologic processes.

The development and maturation of the Martian crust would, in light of evidence for a hydrosphere, result in thermally driven convection cells of dominantly aqueous fluids adjacent to shallow intrusive igneous bodies. Terrestrial analogs would include the Skaergaard Intrusion in Greenland and many porphyry-hosted Cu deposits of the southwest U.S. Convecting aqueous fluids leave definite light stable isotopic and geochemical signatures as well as abundant fluid inclusions. Intrusive igneous rocks may be exposed at the surface by major tectonic processes coupled with erosion, by large impact excavations, or by more local uplift and exposure (such as caldera formation).

Sample requirements for a Martian return mission are not too stringent for this proposed study. Any solid rock that can be thin sectioned provides a potential host material (whether it has usable inclusions is another matter). Rocks from anywhere on Mars would be welcome but the best samples would come from rifts (Valles Marineris) and fractures on the flanks of, or from the caldera rims of, the large volcanic edifices (i.e., Olympus Mons, Tharsis Ridge, Eylsium Planitia bulge). Another interesting area would be near the polar regions where the regolith and upper crust are likely saturated with a (frozen) fluid phase. Nearby igneous activity could melt the trapped fluid and allow it to be preserved as fluid inclusions.

For this study, sample handling and return restrictions are unlikely to be as restrictive as the needs of other investigators. The main constraint is that the samples not be subjected to excessively high T. As the collected samples do not undergo more extreme P-T conditions than they have been subjected to on the Martian surface, the information that they presently contain will make it back to the laboratory.

In summary, appropriate samples returned from the Martian surface will likely contain fluid inclusions that will yield compositional as well as P-V-T data for a range of igneous and hydrothermal processes. In concert with other studies, these trapped fluids provide a unique and potentially critical piece of the puzzle of understanding Martian crustal evolution. (From the author's abstract by E.R.)

BROWNLOW, A.H. and KOMOROWSKI, J.-C., 1988, Geology and origin of the Yogo sapphire deposit, Montana: Econ. Geol., v. 83, p. 875-880. First author at Dept. Geol., Boston Univ., Boston, MA 02215.

Pertinent in view of the interesting CO_2 inclusions in these sapphires, e.g., Roedder, 1984 M.S.A. Reviews in Mineral., v. 12, p. 491-492. (E.R.)

BUCHER-NURMINEN, Kurt, 1987, The composition of hydrothermal fluids responsible for silicate reaction veins in dolomitic marbles, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 759-762. Author at Univ. Oslo, Dept. Geol., P.O. Box 1047 Blindern, N-0316 Oslo 3, Norway.

Symmetrically zoned silicate-calcite reaction veins occurring in dolomitic marble xenoliths of the Bergell intrusion (Central Alps) have formed by reaction of a SiO_2-rich aqueous fluid with the wall rock dolomite (SiO_2-metasomatism).

Fluid inclusions in hydrothermal quartz from alteration zones in granite along the vein-generating fracture system contain an aqueous solution, a vapor bubble and several solid phases. The optical properties of the solids indicate that carbonates (calcite), chlorides (halite, sylvite?) and fluorides (fluorite) are present. Microthermometric measurements and the presence of the dms show that the total salt concentration in the inclusions is very high. A total chloride concentration of 6 m may be regarded as a conservative estimate. This is also reflected in the presence of metasomatic scapolite (EQAN 54) along the fracture zones which contains 0.6 wt. % Cl and up to 1.0 wt. % SO_3. The scapolite composition shows that sulphur also was present in the metasomatic fluid.

The composition of the fluid generating hydrothermal tremolite + calcite veins in dolomite marble (450°C, 2 kb, Cl (tot) = 6.0 m) is as follows (in moles/litre H_2O; gases in bars):

Continued next page.

NaCl	2.0	H_2SiO_4	0.057
KCl	1.3	HCl	0.002
$CaCl_2$	1.4	HF	0.016
$MgCl_2$	0.015	CO_2	<200
$FeCl_2$	0.012	SO_2	?
		Al	?

(From the author's text by E.R.)

BUCHER-NURMINEN, K., 1988, Transport and composition of mantle fluid into the lower crust (abst.): Chem. Geol., v. 70, p. 36. Author at Dept. Geol., Univ. Oslo, Norway.

Ultramafic rocks occurring in continental associations in the Scandinavian Caledonides (SC) may represent fragments derived from upper mantle beneath the continental crust. Typical continental geotherms result in MOHO T which are well within the stability field for hydrated and carbonated versions of peridotite. Calculated phase relationships in the MSHC system suggest that any mantle fluid (H_2O-CO_2) derived from the lower parts of the mantle will be consumed by chemical reactions in the upper part of the mantle if the MOHO T is below about 600°C. Under such conditions no mantle fluid is able to penetrate the MOHO. The calculations also show that only H_2O-rich fluids from the mantle can infiltrate the lower crust at high T.

Early magnesite is very abundant in ultramafics from the SC. Many of the high grade subcontinental type ultramafics from the SC bear witness of an early serpentinite stage. It is therefore proposed that the hydrated/carbonated versions of peridotite found in the SC (subcontinental type) represent mantle rocks (mantle serpentinites, soapstones, sagvandites). The possible presence of partially hydrated/carbonated ultramafics in the upper mantle offers a geological explanation for observed seismic reflectors in the upper mantle and for the elevated topography of old continental shield areas. It questions proposed mantle CO_2 infiltration as an explanation for the formation of granulite facies terrains. (Author's abstract)

BULANOVA, G.P., NOVGORODOVA, P.G. and PAVLOVA, L.A., 1988, First finding of melt inclusion in diamond from the pipe "Mir': Geokhimiya, no. 5, p. 756-765 (in Russian; English abstract). Authors at Geol. Inst. of the Yakutian Div. of Siberian Br. of Acad. Sci. USSR, Yakutsk, USSR. (See Translations)

BURLEIGH, R.E., 1987, A stable isotope, fluid inclusion and ore petrographic study of the gold-quartz veins in the Willow Creek mining district, Alaska: MS thesis, Univ. Alaska.

The Willow Creek mining district is situated within the peninsular terrane of southcentral Alaska, 5 km and 25 km north of the Castle Mountain and Border Ranges transcurrent faults respectively. Au-bearing mesothermal quartz veins transect Cu-Mo quartz vein systems within latest Cretaceous tonalite plutonic rocks.

Au vein mineralogy includes pyrite, arsenopyrite, sphalerite, chalcopyrite, zoned As-tetrahedrite, galena, tellurides, bournonite, Cu-Pb-Bi sulfosalts, Au and rare hypogene chalcocite and hematite. Sericitization and carbonatization characterize alteration mineralogy in multiple brecciated and laminated quartz veins. Au:Ag ratio of the veins is 0.46.

Fluid inclusion microthermometry indicate early solutions were CO_2-rich (5-6 mole %), dilute (1.0-2.5 eq. wt. % NaCl) at Th = 300-325°C. Cooler (167 to 267°C), dilute solutions (2.2-6.8 eq. wt. % NaCl) coursed brecciated vein structures, variably boiled and deposited precious metal mineral assemblages.

$\delta^{18}O$(qtz) (-13.5 to -15.4‰, T - 320°C) and $\delta^{13}C(CO_2)$ fluid inclusion (-17.2 to -16.0) stable isotope data on Au veins indicate mineralizing solutions were evolved formation/metamorphic solutions. A positive enrichment in $\delta^{13}C(CO_2)$ is found with increasing elevation in the district. (Author's abstract)

BURLINSON, Kingsley, 1988a An instrument for fluid inclusion decrepitometry and examples of its application: Bull. Minéral., v. 111, p. 267-278. Author at Burlinson Geochem. Svcs. Pty. Ltd., P.O. Box 37134, Winnellie 5789, N.T., Australia.

A decrepitation instrument has been constructed which provides rapid, reliable and fully automated analyses and it has been used to analyze some 3000 samples to evaluate the application of decrepitation data in mineral exploration. Monomineralic samples of 0.5 g of crushed, sieved grains are analyzed and extensive studies have been done using magnetite, pyrite, galena, carbonates and quartz. Quartz vein samples often show three or more distinct decrepitation peaks. A peak at 570°C is related to the weakening of quartz during the alpha to beta phase transition, which facilitates the decrepitation of inclusions. A low T peak (below 300°C) is due to the presence of gas-rich inclusions (the most common gas being CO_2), while the intermediate T peak is due to primary inclusions. Pyrite and quartz of hydrothermal origin usually give strong decrepitation responses whereas sedimentary pyrite or low T cherts give negligible decrepitation. Carbonate samples give very intense decrepitation up to their thermal decomposition T, at which point the decrepitation suddently ceases. Because of the speed and low cost of the analyses, the technique is useful for exploration projects and for scanning and selecting samples prior to conventional microthermometric studies. (Author's abstract)

Also see Fluid Inclusion Research, v. 20, p. 57-58. (H.E.B.)

BURLINSON, Kingsley, 1988b The recognition of variations in sample suites using fluid inclusion decrepitation - Applications in mineral exploration: Geol. Soc. India Memoir 11, p. 67-78. Author at Burlinson Geochem. Svcs. Pty. Ltd., P.O. Box 37134, Winnellie 5789, NT Australia.

Mineral samples often look identical in hand specimen but contain completely different fluid inclusion populations. The decrepitation method provides a rapid and cheap method of observing the variations in the fluid inclusion populations as a means of discriminating between such similar looking samples. It is possible to use decrepitation on samples of pervasive silicification as well as on quartz veins and comparison of such samples shows the relationship between coexisting veins and silicification. Decrepitation responses from vein quartz and chert at Au mines in the Northern Territory, Australia, are quite different and aid in the geological mapping of the area. Opal samples give a particularly characteristic, narrow decrepitation peak while variations between carbonate samples can aid in the discrimination between sedimentary carbonate horizons. Decrepitation differences in magnetite samples at Tennant Creek, N.T., Australia, could not be correlated with the known Au distribution, but do indicate that the ore bodies are quite complex and significantly different from normal sedimentary banded iron formations. Although the method is best used to compare suites of similar samples, in some cases it can also provide an insight into the genesis of the deposits. (Author's abstract)

BURNS, G.L. and HAJASH, A., 1988, The solubility of natural quartz sand at 150°C and 345 bars: An experimental investigation in a flow-through hydrothermal system (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A391. Authors at Dept. Geol., Texas A&M Univ., College Station, TX 77843.

In order to investigate quartz dissolution under conditions that may closely approximate those of burial diagenesis, natural quartz sand was reacted with distilled water at 150°C and 345 bars in a flow-through hydrothermal system. This apparatus, which holds a 150 cc sample, enables extraction of pore fluid for analysis without affecting the T, P, or instantaneous water/rock ratio. The pore-fluid system is constructed of relatively non-reactive materials (titanium, Inconel, teflon) and is isolated from the confining-P medium. The starting solid consisted of unconsolidated sand (0.18 to 0.25 mm fraction) from the St. Peter formation that was washed in dilute HCl and rinsed repeatedly with distilled water. The initial porosity was 37% (instantaneous water/rock ratio - 0.22) and the average volumetric flow rate was maintained at 1.7 ml/day.

Changes in the fluid chemistry indicate that the dissolution of quartz was rapid. The silica content of the pore fluids reached 210 ppm after 146 hours and then began to decrease very slowly. It took 1777 hours for the dissolved silica concentration to decrease from 210 to 177 ppm. This decrease, although very slow, indicated that the pore fluid was supersaturated with respect to quartz. To approach the solubility of quartz from undersaturation, the sample was "flushed" with 85 ml of distilled water in 2 hours while maintaining the T/P conditions. After this treatment, only 71 hours elapsed before the pore fluid reached a steady state concentration of 161 ± 7 ppm. Following two subsequent "flushes," the dissolved silica content reached 158 ± 5 ppm and 163 ± 7 ppm, respectively. Initial results from an experiment in which the St. Peter sand was pre-treated with HF show that the pore fluid reached a steady-state silica concentration of 168 ppm in approximately 141 hours.

Results from this investigation indicate that the solubility of quartz at 150°C and 345 bars is 161 ± 7 ppm. This is substantially higher than solubilities calculated from empirical models, which yield values between 130 and 144 ppm. In addition, it appears that waters reacting with natural quartz sands may become supersaturated with respect to quartz in the early stages of diagenesis. (Authors' abstract)

BURNS, R.G. and SOLBERG, T.C., 1988, Iron oxidation state in Antarctic shergottite EETA 79001: Reports of Planetary Geological and Geophysical Program, 1987, NASA Tech. Report No. 4041, p. 121-123.
Indexed under "Fluid Inclusions." (E.R.)

BUTTERFIELD, D.A., McDUFF, R.E., LILLEY, M.D., MASSOTH, G.J. and LUPTON, J.E., 1988a, Chemistry of hydrothermal fluids from the ASHES vent field: Evidence for phase separation (abst.): EOS, v. 69, p. 1468. First author at Sch. Oceanography, Univ. Washington, Seattle, WA 98195.

Analysis of hydrothermal fluids from the ASHES vent field in the caldera of Axial Volcano on the Juan de Fuca Ridge during submersible cruises in 1986, 1987 and 1988 has revealed the presence of two chemically distinct hydrothermal endmembers within a single vent field of approximately 50 m radius. One of these is a 'normal' hydrothermal endmember, enriched in calcium, metals and sulfide, with a chloride concentration slightly above ambient sea water. The other endmember shows a previously unobserved chemistry depleted in chloride and ore-forming metals, but showing high concentrations of H_2S and dissolved gases (173 mmol/kg condensable gas). Dissolved silica concentrations from 1986 and 1987 indicate that the low-chloride endmember is below quartz saturation levels. Gas analysis indicates that CO_2 is very high, relative to other vent fields, in all vent fluids from the ASHES field; the highest values are found in the low chloride fluids (endmember CO_2 = 150-170 mmol/kg), while the normal-chloride fluids are a factor of three lower. The chemical data, together with measured T (326°C) near the predicted boiling point (348°C) support the hypothesis that hydrothermal fluid rising through the ocean crust underwent subcritical phase separation, which generated a low-salinity vapor phase. The vapor phase has become partially segregated from the parent fluid and exits the seafloor at several locations marked by the presence of nearly pure anhydrite. Preliminary data from 1988 suggest that the chemistry of individual vents has remained relatively constant over the 2-year period of observation. (Authors' abstract)

BUTTERFIELD, D.A., McDUFF, R.E., LILLEY, M.D., MASSOTH. G.J., and LUPTON, J.E., 1988b Evidence for phase separation of hydrothermal fluids from Axial Volcano, Juan de Fuca Ridge (abst.): EOS, v.69, p.303-304. First author at School of Oceanography, Univ. of Washington, Seattle, WA, 98195.

Analysis of hydrothermal fluids from the ASHES vent field in the caldera of Axial Volcano on the Juan de Fuca Ridge during submersible cruises in 1986 and 1987 has revealed the presence of two chemically distinct hydrothermal endmembers within a single field of ≈50 m radius. One of these is the "normal" hydrothermal endmember, enriched in Ca, metals, and sulfide, while the other shows a previously unobserved chemistry depleted in chloride and ore-forming metals, but showing high concentrations of H_2S and very high levels of dissolved gases (173 mmol/kg condensable gas). Ca is near seawater concentration in the low-chloride endmember, based on extrapolation to zero. Gas analysis has not yet been completed, but the other chemical data, together with measured T (326°C) near the predicted boiling point (348°C) support the hypothesis that hydrothermal fluid rising through the ocean crust underwent subcritical phase separation, which generated a low-salinity vapor phase. The low-salinity phase has somehow become separated from its parent fluid and now exits the seafloor at several locations marked by the presence of nearly pure anhydrite. (From the authors' abstract)

CABLE, M. and FRADE, J.R., 1988, The influence of surface tension on the diffusion-controlled growth or dissolution of spherical gas bubbles: Proc. R. Soc. Lond. A, V 420, p. 247-265. First author at Div. Ceramics Glasses & Polymers, Univ. Sheffield, Northumberland Rd., Sheffield S10 2TZ, UK.

Surface tension can markedly affect the growth or dissolution of small gas bubbles but, even when spherical symmetry is maintained and the interfacial concentration assumed constant, generally valid analytical solutions for the change of size with time cannot be obtained; approximations of limited validity are therefore often used. However, accurate and efficient methods for computing the diffusion-controlled growth or dissolution of spheres in such conditions have recently been developed; the results obtained when interfacial solute concentration is assumed constant have been published and validated by comparing them, where possible, with the equivalent analytical solutions. This paper extends that work to include the effects of a constant surface tension, for both Henry's and Sievert's laws. The numerical results are valid for as wide a range of parameters as is likely to be needed and are compared with the few analytical solutions available for particular cases.

It is shown that, when surface tension is introduced, a complete description of the problem requires an additional saturation parameter as well as the dimensionless surface tension. It is also shown that Henry's and Sievert's laws can have very different effects on dissolving bubbles: when Sievert's law applies a higher surface tension can increase time for a bubble to dissolve but this paradox can be resolved by examining the competing effects involved. (Authors' abstract)

ČADEK, J. and MALKOVSKÝ, M., 1988, Fluorite in the vicinity of Teplice Spa in Bohemia - A new type of fluorite deposit: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 297-307. Authors at Geol. Survey, Malostranské námesti 19, CS-118 21 Prague 1, Czechoslovakia.

The fluorite occurrence in the Teplice Spa area represents an unusual type of stratabound fluorite that formed by circulation of warm water throughout shallow aquifers in sedimentary rocks. Fluid inclusion studies indicate a very low T of fluorite formation. Most inclusions contain only the liquid phase. The only measurable inclusions with liquid and gas yielded Th of 65-76°C. The highest T was estimated from fluorite filling the fissures at Písečný vrch Hill, which represent the earliest phase of fluorite formation in this area. The Th was 133°C and corresponds with the T determined from fluorite inclusions in the nearby Jílové deposit of similar origin. The isotopic analyses of carbon and oxygen in the calcite, which occurs rarely in the mineralization, indicate T close to present-day warm water, 52.6°C. (From the authors' text by H.E.B.)

CAFFEE, M.W., HUDSON, G.B., VELSKO, Carol, ALEXANDER, E.C., Jr., HUSS, G.R. and CHIVAS, A.R., 1988, Xenon from CO_2 well gases (abst.): Lunar & Planet. Inst. Symp. on Origin of the Earth, Berkeley, CA, Dec. 1-3, 1988, LPI Contribution No. 681, p. 9-10.

CAI, Jianming, 1988, A fluid inclusion study of the Pianyanzi gold deposit in Sichuan Province: J. Chengdu College of Geol., v. 15, no. 2, p. 5-10 (in Chinese; English abstract). Author at Chengdu College of Geology.

Pianyanzi Au deposit consists of a specific type of sellaite (MgF_2) ores. Au-mineralization occurred in many stages. Fluid inclusion study shows that the ore-forming fluid were hot geothermal brines enriched in K^+, Cl^- and CO_2. From earlier to later stages, T, salinity and P of the hot brines systematically decreased and their chemical composition as well as physical properties also remarkably changed. The most favorable condition of Au-mineralization is medium-to-low T (240-120°C), moderate-to-low salinity (15-7 wt % NaCl) and in a weak acidic and slightly reducing environment. (Author's abstract)

CAMERON, E.M., 1988, Archean gold: Relation to granulite formation and redox zoning in the crust: Geology, v. 16, p. 109-112. Author at Geol. Survey of Canada, Ottawa, Ontario K1A 0E8, Canada.

The Archean was the principal period for Au mineralization. These rocks compose ~12% of the exposed crust but have produced more than half of the world's Au. Most major lode deposits formed at 2.7 ± 0.2 Ga. This corresponds to the principal time of crustal thickening and stabilization, an essential part of which was formation of granulite, the anhydrous, refractory base for the crust. Upward streaming of mantle CO_2 along shear zones in the lower crust is one means for dehydrating amphibolite to form granulite and is accompanied by removal of large ion lithophile (LIL) elements to higher crustal levels. Archean lode-Au deposits were formed along major shear zones at intermediate crustal depths. They are enclosed by zones of CO_2 metasomatism, many of them kilometers in extent; $\delta^{13}C$ data indicate that the CO_2 is juvenile. Some major Archean deposits have been shown to have formed from relatively oxidized hydrothermal fluids. CO_2 streaming with LIL-element depletion could only have occurred under relatively oxidized conditions that permitted a free CO_2 vapor to exist in the lower crust. Such conditions would also have favored dissolution of Au and associated sulfide and their transfer to the mid-crust in a CO_2-H_2O fluid, the H_2O coming from dehydration of amphibolite. (Author's abstract)

CAMPBELL, Andrew, ROBINSON-COOK, Sylveen and AMINDYAS, Cornelius, 1988, Observation of fluid inclusions in wolframite from Panasqueira, Portugal: Bull. Minéral., v. 111, p. 251-256. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

See Fluid Inclusion Research, v. 20, p. 63. (H.E.B.)

CAMPBELL, A.C., BOWERS, T.S., MEASURES, C.I., FALKNER, K.K., KHADE,. Mitra, and EDMOND, J.M., 1988, A time series of vent fluid compositions from 21°N, East Pacific Rise (1979, 1981, 1985), and the Guaymas Basin, Gulf of California (1982, 1985): J. of Geoph. Res., v.93, n.B5, p.4537-4549.

CANDELA, P., 1988, On progressive magmatic aqueous phase evolution (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 34. Author at Dept. Geol., Univ. Maryland, College Park, MD 20742, USA.

During the course of magmatic vapor evolution, progressive changes occur in the composition of the aqueous phase. Depending on their behavior during the evolution of the vapor, many elements can be placed in one of two classes: chloride-aqueous compatible or crystal incompatible. Cl and the strongly Cl-complexed elements, e.g., Cu, Mn, and Zn, may achieve rather high concentrations early during progressive second boiling. On the other hand, elements which possess rather low vapor/melt partition coefficients but are dominantly xl incompatible, such as Mo, B, F, Nb, W, concentrate very late in the melt and the associated aqueous phase. The later evolved fluids will be enriched in F relative to Cl, and enriched in Mo and B relative to Cu, Mn, and Zn. Furthermore, in many Fe-poor systems (e.g., 2 mica granites or high silica systems) these later fluids may become oxidized by the vapor evolution process, and elevated $f(O_2)$ may accompany the expulsion of Mo and F. Based on recent work in our lab, Mo partitioning into crystalline phases from silicate melts is supressed at high $f(O_2)$ (Thacker and Candela, 1987; Bouton, et. al., 1987). In an orthomagmatic-hydrothermal deposit, the proportion of metal which partitions into hypersolidus minerals is not available for partitioning into an ore-forming fluid. Thus, elevated oxygen fugacities may further enhance the efficiency with which Mo is removed into the fluid. Because the character of the fluids may change rather significantly during a single magmatic fluid expulsion event, several populations of fluids may be detected by fluid inclusion analysis in any given deposit. This may explain the occurrence of coexisting low F/Cl and high F/Cl fluids in some Climax-type deposits. However, the very late Mo, F and possibly W enriched fluids may be trapped within the pluton during its ultimate consolidation, leaving the crystal incompatible elements in a dispersed, albeit hydrothermally labile state. (Author's abstract)

CANIL, Dante, SCARFE, C.M. and OZAWA, Kazuhito, 1988, Phlogopite in mantle xenoliths from the Kostal Lake volcanic center, Wells Gray Park, British Columbia (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 35. First author at Dept. Geol., Univ. Alberta, Edmonton, Canada, T6G 2E3.

Phlogopite has been recognized for the first time in mantle xenoliths from the Canadian Cordillera. The phlogopite-bearing xenoliths are hosted in post-glacial alkali basalt flows and ejecta of the Kostal Lake volcano, eastern B.C. The xenolith assemblage consists of 60% cumulate textured wehrlites and 40% coarse textured dunites and lherzolites.

The phlogopite occurs as: [1] sub-euhedral grains along grain boundaries or as inclusions in olivine in dunite and lherzolite xenoliths or; [2] a replacement of orthopyroxene lamallae exsolved from intercumulus clinopyroxene in the wehrlite xenoliths or; [3] grains hosted in 50-150 μm diameter fluid inclusions in clinopyroxene of all xenoliths. Phlogopites large enough to be analyzed by microprobe ([1] and [2] above) are enriched in TiO_2 (3-8 wt.%) and Cr_2O_3 (1-3 wt.%) with values approaching those found in phlogopites from kimberlite-hosted mantle xenoliths. The phlogopites do not show any reaction relationships and are only zoned in Na_2O content. Phlogopites in a given xenolith have $Mg/Mg + Fe^{2+}$ similar to that of coexisting olivine, clinopyroxene or orthopyroxene and therefore have equilibrated with these phases. The observation that phlogopite occurs as a replacement of orthopyroxene lamellae requires its crystallization in the upper mantle at or below the exsolution T of the orthopyroxene (~1100°C). The Ti-rich nature of the phlogopites and their presence in fluid inclusions suggest that incompatible element-enriched hydrous fluids fluxed this part of the upper mantle prior to, or as a consequence of, Quaternary alkaline magmatism in eastern B.C. (Authors' abstract)

CANN, J.R. and STRENS, M.R., 1988, Hydrothermal vents; surprises of different kinds: Nature, v. 335, p. 495. Authors at Dept. Geol., Univ. Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU, UK.

A brief review of some of the unusual geochemistry involved. (E.R.)

CAO, Xiaoyun, RICHARDSON, S.M. and RICHARDSON, C.K., 1988a Solubility of molybdenite (MoS_2) in hydrothermal solutions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A43. Authors at Dept. Earth Sci., Iowa State Univ., Ames, IA 50011.

We have determined the hydrothermal solubility of molybdenite in NaCl solutions at T from 350° to 400°C under water vapor saturated P. All of the solubility measurements were performed by precipitating MoS_2 from solutions buffered either by Fe_3O_4 - Fe_2O_3 - FeS_2 (MHP) or Fe_3O_4 - FeS_2 - FeS (MPP), to which MoO_3 was added as the source of molybdenum. NaCl concentrations were in the range from 0.1 to 4.5 M.

The total concentration of molybdenum in solution varies from below 0.1 ppm to over 10 ppm, increasing with the NaCl concentration in run fluids. These values are 2 to 3 orders of magnitude lower than measured under sulfur-free conditions in our earlier studies. The solubility of MoS_2 in MPP-buffered solutions ($fO_2 = 2 \times 10^{-29}$, $fS_2 = 1 \times 10^{-9}$) is slightly higher than that in MHP-buffered solutions ($fO_2 = 4 \times 10^{-28}$, $fS_2 = 8 \times 10^{-8}$) at 350°C. At 400°C, solubilities under the two buffer conditions are nearly the same. There is no remarkable dependency of MoS_2 solubility on T within the range of these experiments.

We have also calculated the form that molybdenum takes in the solutions. The results of experiments in the sulfur-free system indicate that oxychloro complexes are dominant, and that $MoO_2Cl°$ is most important under the T and oxygen fugacity conditions of these molybdenite experiments. At lower T, however, MoO_3^- may become more important.

Comparisons between experiments in sulfur-free and sulfur-bearing systems suggest to us that substantial amounts of molybdenum, transported in hydrothermal fluids, can be precipitated by reactions like $MoO_2Cl° + 1/2H_2O + S_2 === MoS_2 + 5/4O_2 + H^+ + Cl^-$. (Authors' abstract)

CAO, Xiaoyun, RICHARDSON, S.M., and RICHARDSON, C.K., 1988b Dissolution and speciation of MoO_3 in NaCl solutions at elevated temperatures and pressures (abst.): EOS, v.69, p.528.

CAPRARELLI, G., DE VIVO, B., MAIORANI, A., PERNA, G. and TURI, B., 1988, Stable isotope and fluid inclusion studies in quartz, calcite and sphalerite samples from the Iglesiente and Arburese mining districts (SW Sardinia) (abst.): Mtg. Soc. Ital. Mineral. Petrol., June 1988, Pavia, p. 56.

CAPUANO, R.M., 1988, Hydrogeologic constraints on fluid-mineral equilibria in kerogen-rich geopressured sediments (abst.): Geol. Soc. Am. Abstract Programs, v. 20, p. A259. Author at Univ. Texas at Austin, Bureau Econ. Geol., University Station, Box X, Austin, Texas 78713.

Pore fluid chemistry resulting from the combined effects of sediment geopressuring and thermal degradation of kerogen was calculated for the conditions within a depositionally active, tectonically stable basin having thermal gradients common to a petroleum resource area (20 to 40°C km^{-1}). Three conditions present during diagenesis of kerogen-rich geopressured sediments contribute to the development of a characteristic alteration mineralogy that differs from that which can develop in kerogen-poor or normally pressured sediments: (1) upward flow of fluids (in contrast to the generally downward flow of fluids in normally-pressured sediments); (2) coincidence of the depths of geopressuring with the geothermal T necessary for CO_2 release; and (3) opposing rates of sediment burial and CO_2 and CH_4 transfer into the upward-flowing fluids, which result in the pore fluids becoming enriched, and in some cases saturated, in CO_2 and CH_4.

Three patterns of mineral deposition during diagenesis of kerogen-rich geopressured sediments are predicted. Quartz precipitates from the upwardly mobile pore fluids in response to decreased T; the majority of quartz deposition occurs at the top of the geopressured zone and decreased with increased depth as a result of the decreased flux of upward fluid flow with increased depth. Carbonate deposition should occur above the zone of CO_2 release from kerogen degradation because of the upward flux of CO_2-saturated fluids and subsequent decrease in fluid T, P, and CO_2 solubility. Kaolinite-carbonate could precipitate within and above the zone of CO_2 release for kerogen as a result of silicate dissolution by CO_2-rich acid pore fluids, followed by the potential for paragonite-carbonate and then albite-carbonate precipitation upon CO_2 depletion. Laumontite and anhydrite should not precipitate during diagenesis of kerogen-rich geopressured sediments, but could form during diagenesis of normally pressured or kerogen-poor geopressured sediments. These predicted mineralogic relations agree with observed associations in the kerogen-rich geopressured sediments from the Texas Gulf Coast. (Author's abstract)

CARMICHAEL, I.S.E. and EUGSTER, H.P., eds., 1987, Thermodynamic modeling of geological materials: Minerals, fluids, and melts. Reviews in mineralogy, Vol. 17: Mineral. Soc. Am., 499 pp.

CARROLL, M.R. and RUTHERFORD, M.J., 1988, Sulfur speciation in hydrous experimental glasses of varying oxidation state: Results from measured wavelength shifts of sulfur X-rays: Am. Mineral., v. 73, p. 845-849.

CARTEN, R.B., GERAGHTY, E.P., WALKER, B.M., and SHANNON, J.R., 1988, Cyclic development of igneous features and their relationship to high-temperature hydrothermal features in the Henderson porphyry molybdenum deposit, Colorado: Econ. Geo., v.83, p.266-296.

CARTEN, R.B., RYE, R.O. and LANDIS, G.P., 1988, Effects of igneous and hydrothermal processes on the compositions of ore-forming fluids: Stable-isotope and fluid-inclusion evidence, Henderson molybdenum deposit, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A94. First author at US. Geol. Survey Mission, APO, New York, NY 09679-7002.

Progessive inward migration of serial crystallization/solidification of magma, accompanied by fracturing, devolatilization, and resurgent-boiling occurred in the apices of the intrusions that host the Henderson deposit.

Successive aliquots of melt were depleted in H_2O, Cl, and many transition elements. These processes, without meteoric water influences, produced systematic variations of high T fluid, stable-isotope and whole-rock compositions that correlate with the time-space igneous features of individual stocks and the density of qts ± mly veins. Specifically, igneous quartz in the intensely quartz-veined, pegmatite-rich border units in the apex of the Seriate stock, has $\delta^{18}O = 9.5$, $\delta D(H_2O)$ of inclusion fluids = -137, and FI of 62 eq. wt. % NaCl with no evidence of generation in a two-phase $NaCl-H_2O$ field. $\delta^{18}O$(qtz) and $\delta D(H_2O)$ of inclusion fluids increase to 10.2 and -92, respectively, and salinity decreases to 16-20 eq. wt. % NaCl downward and inward within the stock toward the unveined and unmineralized core. The δD of coexisting biotites ranges from -141 to -165. The $\delta^{18}O$ of these biotites (5.5 to 8.0) and K-feldspar (5.2 to 7.8) was reset in a closed system during cooling of the stock. $\delta^{18}O$(qtz) in outward-dipping qtz ± mly veins that are concentric to the stock varies as a function of changing position of fluid source within the stock and distance from the stock margin. $\delta^{18}O$(qtz) increases by 0.5 per mil over a distance of 150 meters (apex derived = 9.4 to 9.9; interior derived = 10.0 to 10.5) and correlates with decreasing maximum salinity in inclusion fluids. These variations are best explained by isobaric cooling (0.4°C/m) of fluids and precipitation of halite. Decreasing Cl concentrations in fluids evolved at the level of final magma emplacement controlled partitioning of base-metals between the melt and the fluids and probably also influenced fractionation of hydrogen and oxygen isotopes. $\delta^{34}S$(mly) increases irregularly from 4.8 to 8.9 in the veins outward from the stock. H_2S-dominant fluids followed a T-fO_2 path near the po-py-mt buffer. Enrichment of ^{34}S and depletion of D of the bulk magma may reflect local degassing and/or earlier degassing of deep-seated magma that was the parent of earlier intrusions. Local enrichment of D in the fluids may reflect H_2 loss during crystallization. (Authors' abstract)

CARUSO, L.J., BIRD, D.K., CHO, M. and LIOU, J.G., 1988, Epidote-bearing veins in the State 2-14 drill hole: Implications for hydrothermal fluid composition: J. Geophy. Res., v. 93, no. B11, p. 13,123-13,133. First author at Dept. Geol., Stanford Univ., Stanford, CA.

Epidote-bearing veins in State 2-14 drill core from 900 to 2960 m were examined. Thermodynamic analyses of phase relations among vein-filling minerals and aqueous solutions at depths near 1867 m and 300°C indicate that the modern reservoir fluid in the Salton Sea geothermal system is in equilibrium with calcite + hematite + quartz + epidote (X_{Ps} = 0.33) ± anhydrite. The predicted fugacity of CO_2 (~14 bars) for the modern Salton Sea brine is in close agreement with the calculated value of fCO_2 for the 1867 m production fluid. Theoretical phase diagrams in the system $CaO-K_2O-Fe_2O_3-Al_2O_3-SiO_2-H_2O-O_2-S_2-CO_2$ demonstrate that the mineralogies and mineral parageneses recorded in epidote-bearing veins and the observed variations in $Al-Fe^{3+}$ content of vein epidotes may result from only minor changes in the fugacity of CO_2, O_2, and S_2 of the geothermal fluid. (From the authors' abstract)

CASTLEMAN, A.W. Jr., and KEESEE, R.G., 1988, Gas-phase clusters: Spanning the states of matter: Science, v.241, p.36-42. Authors at Dept. of Chem., Penn. State Univ., University Park, PA 16802.

A review of the status of research that is pertinent to understanding of critical phenomena seen in fluid inclusions. (E.R.)

CATHELINEAU, M., 1987a Existence of contrasting pressure-temperature couples in geothermal fields (abst.): Bull. de Liaison de la Soc. franc.

de Min. et de Crist., v. 110, no. 5, p. 105-106 (in French). Author at CREGU and G.S. CNRS-CREGU, BP 23, 54501 Vandoeuvre, France.

P and T have been estimated in the geothermal field of Los Azufres by using fluid inclusion data, and the physico-chemical properties of geothermal fluids discharged at the wells. The study shows that P are low (50 to 150 bars), even at great depth. Such P are lower than expected considering a hydrostatic P gradient, and a column of liquid from surface to depth. The fluid column is composed of the superposition of several zones of which some contain two immiscible phases: V and L. Specific enthalpy measurements of the resulting fluids confirm this, and indicate that the mixture sampled on surface must be born of an inhomogeneous fluid, containing two phases at depth. Direct P measurements corroborate this.

Estimated P are much higher at Larderello (Italy) based on its historical record. Minimum Pt of the fluids are around 1 kbar at T between 500 and 550°C in the early stages. In the following stages, P are however closer to hydrostatic P regimes, although in some cases, many arguments speak for a transitional regime between hydrostatic and lithostatic P.

These observations must be considered when interpreting data from ancient hydrothermal systems. In particular, P lower than the P of a column of water can be expected, as well as P regimes between hydrostatic and lithostatic P. Such conditions are known to exist in sedimentary basins. (Author's abstract, translated by R. Moritz)

CATHELINEAU, M., 1987b Hydrogen metasomatism in geothermal fields: A geothermometric approach involving fluids and mineral compositions (abst.), *in* H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 757. Author at CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

T in an active hydrothermal system may be estimated by a good number of techniques. Today 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 chemical composition of the pumped up fluids. T data on crystallization of authigenic minerals produced by water-rock interactions are obtained from microthermometric study of trapped fluids in quartz, carbonates or epidote. These different approaches were used on a same geothermal field, Los Azufres (Mexico). There is a good agreement among the values calculated from different geothermometers. In general, there is a little underestimation (-10 to -15°C) of direct measurements compared to geothermometric estimations, which may be due to the delay in reaching complete thermal equilibrium. (From the author's abstract by E.R.)

CATHELINEAU, M., 1987a Fluid-rock interaction: thermometry and modeling. Example of a modern geothermal system (Los Azufres, Mexico), and ancient alteration in the Variscan belt (abst.): PhD dissertation, Inst. Nat'l. Polytech. de Lorraine, France (in French; translated by R.P. Moritz).

Fluid-rock interactions have been studied in the modern hydrothermal systems of Los Azufres (Mexico), and Larderello (Italy), and in ancient systems related to granitic intrusions of the Variscan belt. The research has been focused on the geothermometry of the processes, and the simulation of the mass transfers and the interaction between fluids and minerals. (...) A "chlorite" geothermometer (150-320°C), and an "illite" geothermometer (180-320°C) have been developed on the basis of T of formation (fluid inclusion data, chemical geothermometers, and direct measurements), and chemical characteristics of chlorites and illites in the geothermal field of Los Azufres (...). (From the author's abstract)

CATHELINEAU, M. and BOIRON, M.C., 1988, Fluid-mineral equilibria in French hydrothermal gold veins (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 428-430. Authors at CREGU, BP 23, 54501 Vandoeuvre Cedex, France.

Summarizes Raman and microthermometric studies of inclusions from 3 deposits (from the literature) and from 5 other deposits (new work). There are two types of deposits, from dominantly aqueous solutions, and from CO_2-CH_4-H_2O-NaCl-bearing solutions, followed by aqueous solutions. (E.R.)

CATHELINEAU, M., DUBESSY, J., MARIGNAC, C., POTY, B. and WEISBROD, A., 1987, Fluids in granitic environments (abst.): Societa Italiana di Mineralogia e Petrologia, Conf. "Granites and their surroundings," Verbania, Italy, 29 Sept.-3 Oct. 1987, Abstracts, p. 62-63 (in French; English abstract). First author at CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

Three successive generations of fluids will be distinguished:

I. Magmatic fluids. Few direct initial witnesses of this stage are presently observed, because of the frequent recrystallization of the melt inclusions (Naumov et al., 1977). Inclusions exhibit silicate crystal with a fluid phase, and sometimes three phases (at high T): low immiscible melts, a silicate and a saline one, plus a fluid phase (Reyf and Bazheyef, 1977).

II.a. At the end of crystallization, at last, magmatic fluids are exsolved. There are at least three situations where the expression of late magmatic fluids was clearly observed: (a) in B enriched granitic systems, unmixing of a B-rich aqueous brine (up to 60% eq. NaCl) is locally observed, and is reflected by the crystallization of "quartz-tourmaline or "flour" rocks frequently occurring as breccia pipes (Cornwall, Bolivia, for instance) (Charoy, 1979; Grant et al., 1980); (b) in porphyry Cu intrusives, where these fluids are complex brines, characterized by their high T (600°C and more) and high K/Na ratio (Roedder, 1971; Eastoe, 1978; Denis et al., 1980; Ramboz, 1979); (e) in sodolithic granites, such as the Beauvoir granite at Echassieres; these late magmatic fluids appear enriched in Li and F, and are also characterized by their high T (close to the lowered eutectic of ≈ 560-580°C of the F-Li-enriched magma) and high K/Na ratio (Aissa, 1987).

In these two late examples, boiling of exsolved brines (so called secondary boiling) is a common feature. In every case, the early circulations of these late magmatic fluids mark the beginning of rather long-lived hydrothermal circulations involving fluids of non-magmatic origin.

II.b. Even in the absence of evidence of late magmatic fluids, early interactions of aqueous-dominated fluids coming from the surrounding of the intrusions is often recorded and sometimes spectacularly; such is the case for: (a) the greizenisation process, involving "meteoric" waters (Jackson et al., 1982) at high T (up to 500-550°C) (Charoy, 1979); and (b) the reducing effect of CO_2-CH_4 aqueous fluids evolved from graphite-rich gneissic levels onto the alaskitic magma of Rössing, yielding the massive crystallization of uraninite (Cuney, 1980).

Fluids evolved from devolatilization of C-rich (meta)sediments are a rather frequent compound of high T fluid circulations in granites, as exemplified by those observed in the intragranitic contact zones in the southern part of the French Massif Central (Bondons, Mt Lozère) which are similar to those observed in Sn-W veins (Ramboz et al., 1985; Weisbrod, 1986; Dubessy et al., 1987). These fluids have rather low fO_2, controlled by equilibrium in the C-O-H-N system (± graphite).

III. After cooling, most granites are again submitted to fluid circulations induced either by their own peculiarities (HHP granites, Fehn and Cathles, 1978, for instance) or by subsequent thermal disturbances (late magmatic intrusions, for instance). Fluids developed local to relatively pervasive subsolidus alterations. Quartz dissolution together with K or Na metasomatism, pervasive chloritization, and structured crystallization of phyllosilicates (phengites) are the main observed processess. In most cases, fluids are meteoric, have aqueous compositions and low salinities, of the mineralogical assemblages.

Low T (80-120°C) alteration of granites give diffuse and extended alteration of feldspars and phyllosilicate into smectites (Cathelineau, 1987).

In conclusion, careful studies clearly demonstrate that ore deposition may occur at any stage, thus the orthomagmatic models of ore generation are too simple. Most observed trapped fluids appear to be of late generation more or less associated with rather low T fluid circulations ($\leqslant$ 400°C) and earlier stages have often been more or less overprinted, and may be difficult to recognize. (From the authors' abstract, by E.R.)

CATHELINEAU, M., MARIGNAC, Ch., DUBESSY, J., POTY, B., WEISBROD, A., RAMBOZ, Cl. and LEROY, J., 1988, Fluids in granitic environment: Rendiconti Della Soc. Italiana Di Mineral. E Petrol., v. 43-2, p. 263-274 (in French; English abstract).

Fluids play an essential role for mass and heat transfer in granitic bodies, and their surroundings, at any time after their emplacement. Recent combined stable isotope and fluid inclusion studies have largely improved the knowledge on the characteristics of such fluids, and on the processes controlling the fluid production and circulation. Thus, different fluids can be identified, and roughly described as follows: 1) magmatic water, unmixed from the late stage melt; 2) early (metamorphic) fluids, generated in the surrounding rocks during the early stage of the granite emplacement; 3) late external fluids (of any origin but mainly of meteoric derivation), circulating as a consequence of either pluton cooling, or any reheating (HHP granites, new magmatic intrusion, ...).

The long-lived and multistaged fluid circulation in cooled granites has usually overprinted the earliest fluids. This late hydrothermal activity caused also a significant disturbance of the mineralogical and geochemical features of the granite, and is responsible for a great part of the element (especially those of metallogenic interest) transfers. (Authors' abstract)

CHANGKAKOTI, A., GRAY, J., KRSTIC, D., CUMMING, G.L., and MORTON, R.D., 1988, Determination of radiogenic isotopes (Rb/Sr, Sm/Nd and Pb/Pb) in fluid inclusion waters: An example from the Bluebell Pb-Zn deposit, British Columbia, Canada: Geochim. Cosmo. Acta, v.52, p.961-967. First Author at Dept. of Physics, Univ. of Alberta, Edmonton, Canada T6G 2J1.

Rb, Sr, Pb, Nd and Sm isotopes were determined in fluid inclusion waters extracted from quartz samples of the Bluebell Pb-Zn deposit, British Columbia. The results demonstrate that radiogenic isotopes in fluid inclusion waters can constitute useful geochronological and genetic tools when applied in conjunction with geological, geochemical and other geochronological studies.

Rb/Sr isotopes of fluid inclusion waters and of mineralized marbles hosting the deposit indicate a Tertiary mineralization age of 19.2±5.9 Ma, and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7143. This Rb/Sr date is in general agreement with a Cenozoic age suggested by geologic field relations described by other workers. Pb isotopic data suggest two isotopically distinct fluids, one less radiogenic and similar to values measured on galenas, and the other more radiogenic. This is in agreement with an earlier hypothesis of two-meteoric-hydrothermal fluids, and a convection cell model. Nd and Sm isotope also suggest mixing of fluids. Both Pb/Pb and Nd/Sm data suggest very old lower and upper crustal materials as possible source of the metals. (Authors' abstract)

CHAREF, A. and SHEPPARD, 1988, The Malines Cambrian carbonate-shale-hosted Pb-Zn deposit, France: Thermometric and isotopic (H, O) evidence for pulsating hydrothermal mineralization: Mineral. Deposita, v. 23, p. 86-95. Authors at Centre de Recherches Pétrogr. & Géochim., B.P. 20, 54501 Vandoeuvre-lès-Nancy, Cedex, France.

Microthermometric, stable iostope (D/H, $^{18}O/^{16}O$), and Raman spectroscopic data are given for four different mineralization events located beneath a Triassic unconformity. These events include the Pb-Zn-bearing K_{II} mineralization which fills geodes and fractures in the main karstic mineralization K_I and the F mineralization which fills fractures in the Cambrian carbonates and shales. Post-K_I, pre-K_{II}, and F mineralization fluids were hot (~150°C), moderately saline (~10 eq. wt% NaCl), and precipitated red dolomite. Subsequently, equally hot but more saline (~20 eq. wt% NaCl) fluids deposited white dolomite and then sphalerite of the F mineralization; they were followed by another generation of dolomite at about 70°C from fluids with about 15 eq. wt% NaCl and, even later, barites (~165°C, 10 eq. wt% NaCl). Variation in the Th with salinity for the different dolomite generations suggests that the hot saline fluids were repeatedly diluted by a cooler, less-saline fluid. The fluids are interpreted to be of formation-water origin having possibly developed in the deep levels of the Rhone basins to the southeast, which was at least 3 km thick at the time of mineralization (post-Hetangian). The inferred metal-bearing hot brines were probably episodically expulsed during the dewatering of the basin, depositing their mineralization in the more permeable fault and karstic zones associated with the uplift of the St. Bresson horst. Cold surface waters probably invaded the mineralized zones between the pulses of hydrothermal solutions. This hydrothermal model with the introduction of sulfides can account for the precipitation and dissolution textures associated with the hydrothermal mineralizations. (Authors' abstract)

CHARLES, R.W., JANECKY, D.R., GOFF, Fraser and McKIBBEN, M.A., 1988, Chemographic and thermodynamic analysis of the paragenesis of the major phases in the vicinity of the 6120-foot (1866 m) flow zone, California State well 2-14: J. Geophy. Res., v. 93, no. B11, p. 13,145-13,157. First author at Los Alamos Nat'l. Lab., Los Alamos, NM.

The major phases found in the vicinity of the 1866 m flow zone are K-feldspar, epidote, pyrite, hematite, and chlorite. These are found to exist in primarily four, two-phase assemblages, the dominant being K-feldspar + pyrite, epidote + pyrite, epidote + hematite, and chlorite + pyrite. Complete reaction relations among these isobaric isothermal divariant phase assemblages oriented in log fO_2-pH space are compatible with stable growth at 300°C. Sensitivity of reaction relations to total sulfur, T, P, and thermodynamic values is investigated. The aqueous fluid sampled at 1866 m is out of equilibrium with the more reducing phase assemblages lying stratigraphically above and below the flow zone as well as pyrite-bearing assemblages in the flow zone and shows aspects of mixing with other, hotter, flow zones. High concentrations of CO_2 may indicate contribution to the fluid of CO_2 from hotter portions of the system. Low total sulfur and high total iron are due to possible gas loss during down hole sampling and reaction of the fluid with well casing and lost circulation materials. (Authors' abstract)

CHARLOU, J.L., DMITRIEV, Leonid, BOUGAULT, Henri and NEEDHAM, H.D., 1988, Hydrothermal CH_4 between 12°N and 15°N over the Mid-Atlantic Ridge: Deep-Sea Research, v. 35, no. 1, p. 121-131. First author at IFREMER/Centre de Brest, BP 337, 29273 Brest Cedex, France.

Hydrothermal effluents enriched in gases such as He, H and CH_4 have been found outgassing from mid-ocean ridge zones, crustal rifts, volcanoes and other areas of tectonic activity. Although CH_4 is not conservative in sea water, its analysis on board ship can be used qualitatively or semi-quantitatively to locate hydrothermal fields as a cruise progresses. Between 12° and 15°N over the Mid-Atlantic Ridge, CH_4 anomalies (up to 44 nl l^{-1}) in the water column reveal the presence of plumes originating from hydrothermal discharge. The large amplitude of the CH_4 anomaly at one station (Hy-36) integrated over more than 1000 m, reflects a large CH_4 input and thus extensive hydrothermal activity in this slow spreading section similar to inputs from fast spreading sites like the East Pacific Rise. (Authors' abstract)

CHATTERJEE, A.K., and GILES, P.S., 1988, Meguma zone basement II: P-T evolution of granulite xenoliths (abst.): GAC/MAC Program with Abstracts, v.13, p.A19. Authors at Nova Scotia Dept. of Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1.

Sapphirine-orthopyroxene, garnet-orthopyroxene, garnet-clinopyroxene, clinopyroxene-orthopyroxene, orthopyroxene-amphibole and clinopyroxene-amphibole granulite xenoliths occur in a mafic dike at Tangier. Xenolith textural and compositional data reveal a three-stage P-T evolution. Second-stage Ti-poor, Al-rich amphiboles with abundant fluid inclusions are typically surrounded by Ti-rich, Al-poor amphiboles devoid of fluid inclusions. Gt-opx and gt-bi mineral pairs give temperatures of 710-820°C (exceptionally, margins indicate 1000°C). Pressure range from 5.6 to 8.7 kb. Stage Three represents a later (low P-T) hydration event affecting both xenoliths and dike matrix. (From authors' abstract)

CHAUSSIDON, M., ALBAREDE, F. and SHEPPARD, S.M.F., 1988, Sulphur isotope variations in the mantle from ion microprobe analyses of micro-sulphide inclusions (abst.): Chem. Geol., v. 70, p. 47. Authors at Centre de Recherches Pétrogr. & Géochim. & ENS Géologie, Vandoeuvre, France.

21 samples of sulphide liquids trapped either as globules or grains in various minerals (olivine, pyroxene, clinopyroxene, ilmenite and garnet) or rocks (basalt glasses, peridotites, eclogites and kimberlites) of mantle origin, have been analyzed for their sulphur isotope, and Cu, Ni, Fe compositions by ion microprobe. The results show a wide range of $\delta^{34}S$ values between -4.9 ± 1‰ and +8 ± 1‰. Sulphides with high nickel contents (up to 40% pentlandite), corresponding mostly to type I peridotites (Lers, Beni Bousera, Ronda, ...), have $\delta^{34}S$ values ranging from -3.2‰ to +3.6‰ with a mode of +3 ± 1‰, compared to low Ni content sulphides, mostly contained in type II peridotites, OIB (Hawaii, Tahiti, ...) and South African kimberlites, ranging from -3.6‰ to +8‰ with a mode of +1 ± 1‰.

These results show a large heterogeneity of the sulphur isotope compositions of the sulphides originating from the mantle. In spite of the high T of melting, a significant sulphur isotope fractionation (+2 ± 1%) between immiscible sulphide melts and sulphur dissolved in the silicate melt is suggested by the present data. The sulphide globules with high Ni-contents and $\delta^{34}S$ values close to +3‰, are probably produced by 10-20% partial melting of a mantle source containing 300 ppm sulphur as an upper limit and having a $\delta^{34}S$ value of +0.5 ± 0.5‰. The mass balance of sulphur isotopes in the system upper mantle + oceanic crust + continental crust + seawater requires a mean $\delta^{34}S$ value of the depleted upper mantle of +0.5‰, significantly different from the $\delta^{34}S$ value of ordinary chondrites (+0.2 ± 0.2‰), Thode et al., 1961) but towards that of lunar basalts (1.2‰, Kaplan et al., 1970). (Authors' abstract)

CHEN, Gengli, 1986, Types and characteristics of tungsten ore deposits in northern Guangdong, China: Proc. of Symp. on Mesozoic and Cenozoic Geol., China, Huang Jiqing, ed., Geol. Pub. House, Beijing, 1986, p. 517-534. Author at Metallurgical Geol. Inst. Guangdong, Guangzhou, China.

Northern Guangdong is one of the important productive areas of W-ore deposits in China. According to the genesis, geological features of W-deposits and their commercial value, the W-ore deposits can be divided into 5 types: A. Granitic hydrothermal type, including 4 subtypes: (1) disseminated ores in granite; (2) fine vein disseminated ores in greisens; (3) mineralized skarns; (4) quartz veins; B. Porphyry type; C. Volcanic-sedimentary hydrothermal reworking type; D. Sedimentary reworking type; E. Placers. The details of each type and subtype of W-ore deposits including the description of the regional geological background, the geological features of ore deposits, their commercial value, and the discussion of their genetic mechanism are given in this article. (Author's abstract)

Presents F.I. decrepitation data for some deposits. (H.E.B.)

CHEN, Xianpei and GAO, Jiyuan, 1988, Thermal water deposition and Pb-Zn barite deposits in the Devonian System, Central Guangxi: Chinese J. Geochem., v. 7, no. 4, p. 321-328. Authors at Inst. Geochem., Acad. Sinica, PRC.

Stratiform barite deposits (SB) and vein Pb-Zn barite deposits (VB) are known in a rift basin in central Guangxi. The former is hosted in the Upper Devonian chert beds and the latter occurs in the Middle and Lower Devonian neritic sediments. The two types of mineralization are believed to have a common origin as evidenced by the following observations: (1) Spatially, they are closely associated with each other. (2) They possess a basic similarity, but also show systematic variations from VB to SB in terms of ore composition, structural and textural features, T of mineralizing solutions, country rocks and alteration. (3) Their $\delta^{34}S$ values are more similar to the average value of marine sulfate in Late Devonian than to that in Early Devonian. A model of thermal water deposition has been proposed to illustrate the genesis of these deposits. (Authors' abstract)

Analyses (3) are given for H_2O, CO_2, K, Na, Ca, Mg, F, Cl, SO_4, and total concentration. (E.R.)

CHEN, Yinhan, 1987, On the formation conditions of porphyry Cu-Mo polymetallic deposits in the Xiaosigou district: Geochemistry, v. 6, no. 2, p. 140-152. Author at Inst. Chem. & Mining Geol., Ministry of Chem. Industry.

The host mass consists of quartz diorite-porphyry (marginal facies), granodiorite porphyry (intermediate facies) and granite porphyry (central facies). The petrographic facies are asymmetrically spread. The formation T of the rock mass ranges from 890 to 800°C, the P from 330 to 380 bars and the depth from about 1.5 to 2 km. Mineralization is controlled by the N-E contact zone and adjacent fault structures. Mo-mineralization occurs in the granite porphyry with strong K metasomatism. Cu-Mo-mineralization is distributed in the inner contact zone of the rock mass, and the wall rock is K-silicified granite porphyry. Cu-pyrite-mineralization is recognized in skarn and serpentinite. Pb-Zn ore veins occur in marbleized limestones. Rock and mineral analyses, fluid inclusion studies and high T-P experiments indicate that extensive precipitation of Cu-bearing pyrite took place at T = 290-250°C, and P = 330-380 bars and that of copper at T = 400-310°C and P = 330-380 bars. Precipitation of Pb and Zn was followed by the transformation of hydrothermal solutions from alkaline to intermediate with decreasing T. (Author's abstract)

CHEN, Ziying, 1986, A fluid inclusion study of rare-element mineralized granites in southern China: Mineral Deposits Studies Group Ann. Mtg.: Univ. Southampton, U.K., 15-16 Dec., 1986, Abstracts, p. 25. Author at Wuhan College of Geol., Yujiashan, Wuhan, China.

There are a few tens of rare-element mineralized granites in southern China. Two contrary points of view on the genesis of these granites (metasomatic and magmatic differentiation) have been reported by many geologists. The following fluid inclusion data from more than 15 mineralized granites are provided as very strong evidence to support the magmatic origin:

i) Melt inclusions in topaz and quartz have been discovered in W-Sn-Nb-Ta granites. P gas-rich inclusions always coexist with melt inclusions in topaz. Starting melting T of melt inclusions is 540-650°C. Th is 700-900°C in quartz, 750-800°C in topaz, and 520-550°C for P gas-rich inclusions.

ii) Multiphase immiscible inclusions have been observed in some granites and granite-related pegmatite.

iii) Fluid inclusion data show that fluid evolution from granite-pegmatite-hydrothermal vein was a continuous process.

iv) The medium in which topaz and quartz crystallized was a coexisting melt-fluid system.

v) The possible origin of the Nb-Ta mineralization in Li-, F-rich granites of the Yanshan period in southern China resulted from magmatic differentiation. (Author's abstract)

CHENG, Jingping and WANG, Xiuzhang, 1988, Geological characteristics of Jiapigou gold deposits, a type of late reworked deposit in Archeozoic strata (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 255-257. Author at Inst. Geochem., Acad. Sinica.

The CO_2/H_2O, Ca^{++}/Mg^{++}, HCO_3/Cl^- ratios and total ionic concentration and δD of inclusion fluids in quartz from the ores are similar to those obtained from the strata but differ a good deal from those measured from granites.

The Hercynian grantite and Au-bearing veins are syntectonic products. The close similarity in δD values of inclusion fluid water from the granite and the Au-bearing veins to those from the metamorphic rocks of Anshan formation indicates that the hydrothermal water may have originated from the Anshan formation. (From the authors' abstract)

CHIPLEY, D. and KYSER, T.K., 1988, Basin fluid history as recorded by fluid inclusions in halite (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A152. Authors at Dept. Geol. Sci., Univ. Saskatachewan, Saskatoon, Saskatchewan, S7N 0W0, Canada.

Fluid inclusions in halite record the T and the chemical and stable isotopic composition of the water from which the halite crystallized. Th and hydrogen and oxygen isotopic compositions of FI in halite of the Patience Lake Member of the Devonian Prairie Evaporite Formation in the Elk Point basin vary substantially, which indicates that the evaporite has been extensively recrystallized by several events, each of which is recorded by particular FI. The isotopic composition of the waters in the inclusions are similar to basinal waters from formations above and the Th indicated recrystallization at various depths. Three generations of FI are defined by Th and isotopic compositions and these inclusions represent three major fluid events that affected the Prairie Evporite and the Elk Point and Williston basins. The three major fluid events are most likely related to (1) complete recrystallization of the salts in the Devonian by waters originating from an inland environment, (2) a post Devonian to early Cretaceous event involving waters from an inland sea, and (3) maximum burial during the late Cretaceous, and Tertiary uplift of the basin with recrystallization by waters similar to present day metoric water. (Authors' abstract)

CHO, Moonsup, 1988, The stability of prehnite in H_2O-CO_2 fluids at 0.5 to 3.0 kbar (abst.): Geol. Soc. Am. Abstracts with Programs, v. 7, p. A343.

CHOU, I.-M., 1988a, Halite solubilities in supercritical carbon dioxide-water fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A76. Author at 959 National Center, USGS, Reston, VA 22092.

Halite solubilities in supercritical CO_2-H_2O fluids were determined by using the differential thermal analysis (DTA) technique (Chou, Geochim. Cosmochim. Acta [GCA], 46, p. 1957, 1982). Samples of fixed compositions (circles in Fig. 1 along the composition lines BC, AC, BE, BF, and AD; $Ag_2C_2O_4$ as CO_2 source) were sealed in Pt capsules, and the crystallization of halite in each isobaric cooling scan was detected by DTA signal, with the T of the cold-sealed P vessel used as a reference. Results at 2 kbars are shown in Fig. 1, in which isotherms of the halite-saturated surface in T-X space (halite liquidus) are given in 10°C intervals. Note that CO_2 is quite soluble in NaCl melt, even though it is not as effective as H_2O in depressing the melting point of halite. Also, within the ternary system, the addition of H_2O always decreases the halite liquidus T (HLT), while the addition of CO_2 may, in some cases (such as along line AD), raise the HLT.

The dP/dT slopes for halite-liquidus isopleths are positive and become steeper as CO_2 and/or H_2O content increases. At P below 2 kbars, unmixing (liquid-vapor phase separation) of the ternary fluids was indicated by the false DTA signals for the halite liquidus, similar to those noted in the NaCl-H_2O system at P below 500 bars (detailed in Chou, GCA, 51, p. 1965, 1987). This unmixing event can occur at much higher T than those for the CO_2-H_2O binary fluids. (Author's abstract)

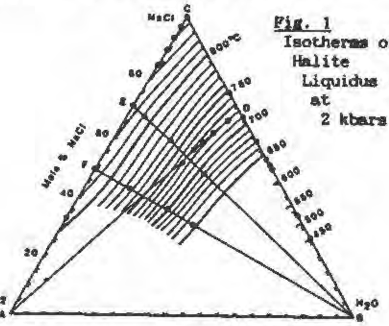


Fig. 1
Isotherms of
Halite
Liquidus
at
2 kbars

CHOU, I.-M., 1988b, Quantitative redox control in hydrothermal experiments (abst.): EOS, v.69, p.528.

CHOU, I.-M., 1988c, The effect of Au-Ag alloying on the Ag-AgCl buffer (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 36. Author at 959 National Center, U.S. Geol. Survey, Reston, VA 22092, USA.

The Ag-AgCl buffer technique of Frantz and Eugster (Amer. Jour. Sci., 267, p. 268, 1973) was modified by Frantz and Popp (Geochim. Cosmochim. Acta (GCA), 43, p. 1223, 1979) to study mineral solubilities and speciation in supercritical chloride solutions. By using the modified method, thermodynamic properties of several aqueous metal chloride were obtained, including $MgCl_2$ (GCA, 43, p. 1223, 1979), $CaCl_2$ (GCA, 43, p. 1777, 1979), NaCl (GCA, 44, p. 1029, 1980), $FeCl_2$ (GCA, 44, p. 1509, 1980), $NiCl_2$ (GCA, 48, p. 2713, 1984), and $MnCl_2$ (GCA, 49, p. 565, 1985). Continued next page.

In the modified method, one or two sealed Pt capsules that contained H_2O-HCl solutions and (Ag + AgCl) were placed in a welded Au capsule that contained the mineral assemblage under study, the metal chloride solution, and (Ag + AgCl). The equilibrium molalities of associated HCl° in the Au capsules were assumed to be equal to those in the Pt capsules because the Ag-AgCl buffer was common to both and the hydrogen equilibrated through the Pt membrane. Unfortunately, this assumption is not always valid due to the formation of Au-Ag alloy in the outer system. As a result, the equilibrium molalities of associated HCl° in the Au capsules in the studies listed above tend to be underestimated; the degrees of these underestimations are not known because the activities of Ag in these experiments are not defined. Erratic reduction of Ag activity in the Au capsules in these experiments may explain (a) the scattering of the data points in the log m(HCl°) vs. log m(total metal) plots under isothermal isobaric conditions and (b) the unsystematic changes of the slopes in these plots as a function of T. Also, the speciation and the free-energy data of aqueous metal chloride complexes reported in the studies listed above need to be reevaluated. (Author's abstract)

CHRYSSOULIS, S.L. and RANKIN, A.H., 1988, Decrepitometry of fluid inclusions in quartz from the Guadalcazar granite of Mexico; principles and application to mineral exploration: Mineral. Deposita, v. 23, p. 42-49. First author at Univ. Western Ontario, Nat. Sci. Center, London, Ontario N6A 5B7, Canada.

A simple acoustic decrepitometric method, with which samples of granite quartz are heated to about 600°C while the number of decrepitations are counted, has been developed to study rock samples derived from the mineralized Guadalcazar granite in Mexico. Decrepitation T for individual inclusions have also been determined by observing the point at which they rupture upon heating using a microscope heating state. Decrepitation T of individual fluid inclusions in granite quartz are influenced by a variety of factors notably size, shape, composition, Th and proximity to the surface. There is a positive correlation between total decrepitation activity and fluid inclusion abundances (determined optically using point counting methods). Decrepitographs show a period of low intensity decrepitation activity below 390°C followed by a period of intensive decrepitation up to 570°C. The onset of massive decrepitation at around 390°C is constant for all samples, but variations in decrepitation activity often occur between mineralized and barren samples. These variations reflect complex differences in the fluid inclusion populations, but illustrate the potential for applying simple audio-decrepitometry as an aid to mineral exploration in granite terrains. (Authors' abstract)

CLARK, R.J.H. and LONG, D.A., eds., 1988, Eleventh international conference on Raman spectroscopy, 5-9 Sept. 1988, London, England: John Wiley & Sons, New York.

CLARKE, Mike and TITLEY, S.R., 1988, Hydrothermal evolution in the formation of silver-gold veins in the Tayoltita mine, San Dimas district, Mexico: Econ. Geol., v. 83, p. 1830-1840. First author at Cyprus Metals Co., P.O. 1126, Green Valley, AZ 85622-1126.

The Tayoltita mine, located in the states of Durango and Sinaloa, Mexico, is a major example of a Tertiary volcanic-hosted Ag-Au epithermal vein deposit. Significant Ag and Au values and base metal sulfides as well as most of the vein quartz and accompanying chlorite, calcite, rhodonite, and adularia are restricted to a vertical interval in the veins between approximately 500 and 1000 m beneath the original surface. Fluid inclusion studies indicate that ore deposition was from fluids averaging ~260°C and was accompanied by some boiling. The salinity of the fluid inclusions is estimated at 0.1 m NaCl eq; greater apparent salinities indicated by lower Tm probably reflect some dissolved CO_2. Correlation of Ag/Au values with the apparent salinities and with vein mineral paragenesis shows that during ore deposition the fluids evolved in time and space from relatively concentrated to dilute conditions owing to gas loss, and possibly, some fluid mixing. Ag/Au ratio zoning, ore body distribution, and vein mineral zoning patterns are all consistent with vein formation from fluids flowing predominantly in horizontal flow patterns. (Authors' abstract)

CLEGG, S.L. and BRIMBLECOMBE, P., 1988, Solubility of acid and alkaline gases in electrolyte solution mixtures (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). First author at Plymouth Marine Lab., Citadel Hill, Plymouth PL1 2PB, UK.

Gas solubility in salt solutions is important in natural systems such as atmospheric aerosols, seawater, brines and liquid inclusions in ice. The equilibrium distribution of a strong acid HX is described in a thermodynamic Henry's law constant K_H ($mol^2\ kg^{-2}\ atm^{-1}$) equal to $mH^+ \,.\, mX^- \,.\, \gamma^2_{\pm}/pHX$. The mean activity coefficient $\gamma_{\pm}$ may be calculated by the Pitzer model. This treatment has been successfully applied to HNO_3 and hydrohalic acid solubility in concentrated salt solutions.

Weak electrolytes require explicit recognition of dissociation equilibria, although different approaches are possible. New work incorporates NH_3 solubility in multicomponent solutions over a range of T, with particular emphasis on seawater and natural aerosols. This is contrasted with a previous treatment of HF. Differences in the behavior of strong and weak volatile electrolytes are discussed, using the displacement of HCl and HF from acidified marine aerosols as an example. (Authors' abstract)

CLINE, J.S. and BODNAR, R.J., 1988, Numerical simulation of Cu and Cl partitioning during vapor evolution in porphyry Cu systems (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A93. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Geologic observations suggest that mineralization in porphyry copper sytems is temporally and spatially associated with separation of a magmatic aqueous phase from the crystallizing magma ("second-boiling"). This process has been simulated using a numerical model that combines theoretical and experimental data describing the partitioning of Cl and Cu into a fluid exsolving from a crystallizing melt. Subsequent redistribution of Cu and Cl during the magmatic-hydrothermal stage has been evaluated based on partitioning of these elements between the coexisting, immiscible liquid and vapor aqueous phases. The model assumes initial P is 2 kb; Cl content equals 3% of the dissolved water present. Cu is modeled as an incompatible element and Cu transport as an aqueous chloride complex is assumed.

Melts of low initial water activity required extensive crystallization (~69%) to produce "second-boiling," and the first aqueous phase to separate from the saturated melt contains abundant Cl (>9 wt%) and enhanced Cu (0.12 wt%). The immiscible high salinity liquid and low salinity vapor phases that form when these early fluids encounter lower P-T conditions contain such elevated Cl concentrations that Cu tends to remain in solution. Thus, extensive crystallization of the saturated melt is necessary so that less Cl is partitioned into the liquid and vapor phases, permitting Cu precipitation. Later exsolved fluids contain sufficient Cl (~2 wt%) to partition significant Cu from the melt (0.11 wt%), yet permit economic concentrations of Cu to precipitate from the saline liquid phase as P-T conditions decline (700°C, 0.6 kb) at the fractured outer margin of the crystallizing magma.

Dispersed copper mineralization of decreasing grade precipitates higher in the system from immiscible liquids which continually partition from the upwardly convecting vapor phase.

Results indicate that a felsic pluton 10 km on a side is capable of producing a copper deposit (>500,000,000 tons, 0.40 wt% Cu) from a single magmatic fluid under the following conditions: low initial water activity (0.2), extensive crystallization of the saturated melt (80%) prior to Cu precipitation, and enhanced initial Cu (0.04 wt%). Thus, marginally economic mineralization can be produced by some magmatic fluids alone. However, grades and tonnages may be significantly enhanced if these fluids interact with a lower T, lower salinity meteoric fluid, decreasing Cu solubility and causing a larger proportion of the total Cu to be precipitated in the immediate vicinity of the pluton. (Authors' abstract)

CLOCCHIATTI, R. and METRICH, N., 1984, Evidence for contamination in the products of the explosive eruptions of M. Silvestri (1892) and M. Rossi (1669) (M. Etna): Bull. Volcanol., v. 47-4, no. 2, p. 909-928 (in French; English abstract). Authors at Groupe de Sci. de la Terre, Lab. Pierre Süe, C.E.N. Saclay, 91191 Gif-sur-Yvette, France.

The melt inclusions trapped inside crystals have allowed the determination of the different crystallization steps, for the M. Rossi and M. Silvestri pyroclastic products.

Magnesian olivine (Fo 82) and diopside crystallize from an alkali basaltic liquid, during ascent. The high concentration (4-5% with S = 2800-3500 ppm) of volatiles in glass inclusions involves a strong fluid P.

The release of about 50% of dissolved gases reflects the "opening" of the magmatic system. Therefore, olivine (Fo 74-70), salite and Fe-Ti oxides, crystallize from an hawaiitic melt, with lower volatile content (2 to 2.5% with S = 1200 ppm). The T range from 1160°C to 1140°C. Plagioclase phenocrysts (An 82) grow later from a more evolved liquid. Equivalences of gas accumulation infer a pre-eruption crystallization.

The unusual content of volatiles in the alkali basalts compared to equivalent oceanic basalts (2% with S = 1200 ppm and Cl = 200 to 400 ppm in olivine melt inclusions from Piton de la Fournaise volcano) suggests wall rock contribution. Numerous xenoliths of carbonates (with fassaite, wollastonite, anorthite assemblages), shale (with plagiocalse, hercynite and sulfide) or sandstone (with quartz and rhyolitic glasses) have been found among the M. Silvestri products.

Fluid inclusions in the minerals as well as local SiO_2, CaO, FeO enrichments of the magmatic liquid infer partial assimilation of sedimentary rocks. All these observations support a contamination hypothesis, at least for the volatile phase. (Authors' abstract)

COELHO, C.E.S., 1987, Contribution to genetic study of fluorite mineralization from Tanguá District, Itaboraí, Rio de Janeiro State (Brazil): M.S. thesis no. 43, Univ. Brasilia (in Portuguese). Author at Dept. Geosci., Univ. Brasilia, 70910, Brasilia, DF, Brazil.

The fluorite vein mineralizations from Tanguá District are associated with the Tanguá Alkaline Complex terrain. The nepheline-syenite plutonic body (Tanguá Massif) is intruded together with dikes and sills of predominantly trachytic and phonoliltic composition in basement rocks (essentially biotite-gneisses). They are all Cretaceous. The fluorite veins are emplaced as much in the basement gneisses as in the Tanguá Massif and dikes.

The REE geochemistry of the mineralization indicate a very low concentration and highly fractionated behavior. Four stages of mineralization have been detected in the deposit: the first represented the original solution;

the second was characterized by a new fluid enriched in Eu; the third represented the evolution of this new fluid in a reducing environment with pyrite precipitation, and the fourth a new introduction of the original solution.

The fluid inclusion study revealed a well defined trend showing the cooling of hydrothermal solutions with concentration of Th around 155°C, 130°C, and 105°C. The salinity of these solutions was always below 2.5 eq. wt% NaCl.

A model linked to the alteration of host rocks by percolating meteoric waters through fractures and faults is suggested from the studies performed. Heated at depth these fluids caused Si, F, and Ca leaching and precipitation of fluorite and chalcedony at the end of ascension. (Author's abstract translated and abridged by K. Fuzikawa)

COLE, D.R. and DRUMMOND. S.E., 1988, Solubilities of calcite and dolomite in hydrothermal solutions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A41. Authors at Chem. Div., Oak Ridge Nat'l. Lab., Oak Ridge, TN 37381.

Experiments have been initiated to measure the equilibrium constants for the principal reactions that control the solubility of dolomite and calcite in hydrothermal solutions: $1/2CaMg(CO_3)_2 + CO_2 + H_2O \rightleftarrows 1/2Ca^{2+} + 1/2Mg^{2+} + 2HCO_3^-$, and $CaCO_3 + CO_2 + H_2O \rightleftarrows Ca^{2+} + 2HCO_3^{2-}$

The experiments were carried out in Au-bag rocking autoclaves containing both calcite and dolomite at 100, 150, 200, 250 and 300°C and 300, 800 and 1300 bars. Approximately one gram of mixed calcite/dolomite (with a mean grain diameter of 18 μ for the mixture) was reacted with water ranging in mass from about 250 to 300 gms and CO_2 concentrations varying from 0.15 to 0.80 m.

The measurements of calcite solubility are in good agreement with results in the literature. The dolomite solubility results represent the only reliable measure of this equilibrium at any condition and show that, in terms of the above reactions, dolomite is 2 to 3 times less soluble than calcite. The solubility of both phases increases by about a factor of 10 between 300 and 1300 bars. These results indicate that the co-solubility method is an effective way to manage solubility studies of phases that share one or more cations and exhibit limited crystalline solution. Co-solubility data of this kind will be used to place constraints on the composition of diagenetic and hydrothermal fluids that are often in equilibrium with both carbonate phases. (Authors' abstract)

COLLINS, C.J., 1988, Geology and genesis of the St. Lawrence fluorspar deposits, Newfoundland (abst.): GAC/MAC Program with Abstracts, v.13, p.A23. Author at Dept. of Earth Sci., Memorial Univ. of Newfoundland, St. John's, Newfoundland, A1B 3X5.

Of the more than 40 known fluorite veins in the St. Lawrence area, most occur within or near [and are related to] the Lower Carboniferous alkaline to peralkaline St. Lawrence Granite. Fluid inclusion studies of a number of veins indicate Th averaging 150°-90°C in fluorite. This is indicative of a high level epithermal environment with Th approximating Tt. Study of successive growth zones indicates that the fluorite precipitation was cyclic and occurred during both increasing and decreasing T and salinity. Trace element analyses show that the fluorite is enriched in Y, Sr, and REE. In successive growth zones REE concentrations vary systematically, suggesting changing physio-chemical conditions during precipitation of fluorite. (From author's abstract)

COLLINS, C.J. and STRONG, D.F., 1988, A fluid inclusion and trace element study of fluorite veins associated with the peralkaline St. Lawrence granite, Newfoundland, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 291-302. Authors at Dept. Earth Sci. & Center for Earth Resources Res., Memorial Univ. Newfoundland, St. John's, Newfoundland.

Detailed study of fluid inclusions in zoned fluorite samples from three veins of the St. Lawrence area reveal two linear trends of T/salinity variation. A trend of slightly decreasing salinity with decreasing T over a wide T range from ~500°C to ~100°C and salinities from 14 to 6 eq wt% NaCl corresponds with that which would result from simple cooling of magmatic fluids as documented by previous workers. A newly recognized second trend is the reverse of this, with sharply increasing salinity over a narrow T range from ~120°C to ~100°C, and requires a different explanation. It could have resulted from mixing of a cool saline connate or other brine with cooled magmatic fluids, although there is no *a priori* reason to suggest the presence of such brines. It could also reflect a drastic increase in the salinity of residual fluids upon removal of vapor during the boiling which was demonstrated by previous workers. This study confirms that deposition took place in a cyclic pattern, marked by abrupt increases in T and salinity followed by more gradual decreases in both. These cycles are also marked by systematic variations in concentration of base metals which fluctuate with salinity and oxidation state, and rare earth elements which reflect steadily more depleted magmatic fluids. (Authors' abstract)

COLTORTI, M., 1988, Immiscibility and element partitioning in the system fayalite-leucite-silica (abst.): Terra cognita, v. 8, p. 60.

COLVINE, A.C., FYON, J.A., HEATHER, K.B., MARMONT, Soussan, SMITH, P.M. and TROOP, D.G., 1988, Archean lode gold deposits in Ontario, Part I. A depositonal model and Part II. A genetic model: Ontario Geol. Survey Misc. Paper 139, 136 pp.

A summary of selected fluid inclusion and stable isotope data for Archean gold deposits in Canada and western Australia is presented in Part I. Part II addresses the origin(s) of the mineralizing fluid by comparing the fluid inclusion characteristics of the Archean systems with well characterized modern hydrothermal systems. (H.E.B.)

COMBREDET, N. and GUILHAUMOU,N., 1987, Fluid inclusions and geothermal fields: A study of hydrothermal quartz in Los Azufres (Mexico) and in Momotombo (Nicaragua): Geotermia, Rev. Mex. Geoenergia, v. 3, p. 215-227 (in Spanish; English abstract). First author at 124 avenue de Villiers 75017 Paris, France.

The microthermometric study of hydrothermal quartz from samples of geothermal wells at Los Azufres, Michoacán, Mexico, and at Momotombo, Nicaragua, proved the usefulness of this technique in the knowledge of a geothermal field.

- At Los Azufres one may easily oppose an Ary vapor well which is cooling simply by comparing some histograms with the boiling curve.

- At Momotombo a gaseous mix of CO_2-CH_4-N_2 is detected by Raman, while the comparison of the curves of T/depth for wells MT-35 and MT-37 allow us to conclude that the former is cooling and the latter is heating.

One the other hand, in well MT-37, the geothermal fluid could have contained up to 0.83 mol% of CO_2 solution. The formation of the quartz would have, therefore, taken place in a boiling environment. (Authors' abstract)

COMSTI, Ma.E.C., DE JESUS, C.V. and MARCELO, Ma.T.R., 1985, Temperatures of gold-quartz vein formation at Olecram Mining Corporation, Jose Panganiban, Camarines Norte as indicated by fluid inclusions: The Philippine Geologist, v.39, no. 1, p. 35-47.

The Au deposit of the Olecram Mining Corporation (former San Mauricio Mining Company) is one among a number of important Au deposits in the Paracale-Jose Panganiban Mining District.

The Au-bearing quartz veins are confined within the granodiorite and are localized within the northeast trending fractures which have developed perpendicular to the axis of elongation of the granodiorite.

Two main generations of quartz have been recognized, each having distinct petrographic features and fluid inclusion content, namely: an earlier stage of grayish, slightly milky to clear quartz containing tiny disseminations of pyrite and a late stage of milky white quartz which is associated with minor pyrite and intimately intergrown with other sulfides such as galena, sphalerite and chalcopyrite.

Th of fluid inclusions in quartz indicate deposition throughout the vein systems in the range 190° to 320°C. Plots of Th of individual vein systems show that the Imbong-Imbong vein system has been deposited from fluids with relatively high T range. Assay results on samples from this vein indicate remarkably high Au values. The filling Th in this study are regarded as minimum T at the time of entrapment and are therefore subject to P correction. The data show systematic variation in T with respect to primary growth zones and crystallographic positions, i.e., there is a general decrease in the T of the depositing fluids during crystal growth.

The fluid inclusion Th data suggest the deposition of ores at Olecram from hydrothermal fluids which are well within the range expected for mesothermal and epithermal fluids. (Authors' abstract)

CONGDON, R.D. and NASH, W.P., 1988, High-fluorine rhyolite: An eruptive pegmatite magma at the Honeycomb Hills, Utah: Geology, v. 16, p. 1018-1021.

CONRAD, M.E., PETERSEN, Ulrich and O'NEIL, J.R., 1988, Isotopic evolution of hydrothermal fluids in the Tayoltita district of Durango, Mexico (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A334. First author at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138.

Previous work in the Tayoltita district has demonstrated a progressive change in hydrothermal circulation from pervasive flow producing widespread propylitic alteration, to fracture-controlled fluid flow, initially forming tiny, isolated veinlets and then the major veins. $\delta^{18}O$ analyses were made of mineral separates and accompanying quartz veins and veinlets from throughout the district to determine the degree to which the isotopic composition of the fluid changed with time and the factors responsible for these changes.

Calculated equilibrium T for mineral pairs from the same sample are far outside the range expected from fluid inclusion measurements (between 200 and 350°C), making it possible to determine relative changes in the ^{18}O composition of the fluids with which the different minerals exchanged. In general, epidote and chlorite equilibrated with the heaviest fluids, followed by quartz in the wall rock, feldspar and finally, quartz in the veins and veinlets. The order of formation of these minerals matches this trend, suggesting that the ^{18}O composition of hydrothermal fluids became progressively ligher with time.

The $\delta^{18}O$ values of each of the different minerals also have strong district-wide variations. Their lowest values (-4.5 for epidote, -2.0 for chlorite, +1.3 for quartz veinlets) are in samples from the lower central part of the system and their highest (+4.3 for epidote, +5.2 for chlorite, +6.2 for quartz veinlets) in samples from the upper edges of the altered area. These variations are too large to have been caused by T changes; they are probably due to changes in the composition of the fluid resulting from differing amounts of fluid/rock interaction. The $\delta^{18}O$ values of quartz in the major veins, however, varies much less and in no regular manner (averaging about +4.5), indicating that there was little interaction between the wall rock and the fluids in the veins. (Authors' abstract)

CONSTANTOPOULOS, James, 1988, Fluid inclusions and rare earth element geochemistry of fluorite from south-central Idaho: Econ. Geol., v. 83, p. 626-636. Author at Dept. Geol. & Geol. Engrg., Univ. Idaho, Moscow, ID 83843.

Epithermal fluorite mineralization of Tertiary age is structurally controlled and is present as fault and fracture fillings and breccia cements. Argillization and silicification of the wall rocks is common and locally intense.

Nearly 400 two-phase (H_2O + vapor), water-rich inclusions with low vapor to liquid ratios yielded mean Th of 130-160°C. Salinities range from 0 to 1.4 eq. wt % NaCl.

The fluid inclusion, geochemical, geologic, geochronologic, and stable isotope data support deposition in Tertiary hydrothermal systems dominated by fluids of meteoric origin. The most important depositional mechanism is believed to be an increase in the pH of the ore-bearing fluids upon interaction with the wall rocks. (From the author's abstract by E.R.)

COOK, K.H., 1986 - See Appendix

COOKRO, T.M., et al., 1988 - See Appendix

CORDIER, Patrick, BOULOGNE, Bruno and DOUKHAN, J.-C., 1988, Water precipitation and diffusion in wet quartz and wet berlinite $A\ell PO_4$: Bull. Mineral., v. 111, p. 113-137. Authors at Lab. Structure et Propriétés de l'Etat Solide, (Assoc. au C.N.R.S. no 234), Univ. Lille Flandres Artois, 59655 Villeneuve d'Ascq Cedex, France.

Annealing wet crystals of quartz and berlinite $A\ell PO_4$ induces water precipitation. The evolution of precipitation has been studied by transmission electron microscopy on samples annealed in various conditions of T, P and duration. At the beginning one observes unresolved small contrast features, then tiny bubbles connected to sessile dislocation loops become visible. These dislocations are nucleated to relax the fluid P in the bubbles. To minimize the corresponding nucleation energy a partial dislocation loop is first nucleated, then a second partial with a complementary Burgers vector rapidly grows in the same plane and joins the first one. By measuring the mean distance X between precipitates for various annealing conditions one deduces the diffusion coefficient D of the water point defects with the help of the relation $X/2 = \sqrt{2D.t}$ where t is the duration of the annealing. One finds in the T range (350-1000°C) for quartz $D(m^2s^{-1}) \approx 10^{-12} \exp(-95 \text{ kJ mole}^{-1}/RT)$.

There is no visible effect of the confining P, at least between atmospheric P and 700 MPa. The α-β transition slightly affects the D values between 500 and 600°C but except for this T range all the other experimental data fit well the above equation. Two theoretical models of water precipitation are developed. They are based on two contrasted hypotheses about the initial mode of water incorporation. In the first case all the water content is assumed to be initially dissolved as a highly supersaturated concentration of substitutional $(4H)_{Si}$ point defects. Water precipitation would thus occur by homogeneous nucleation of critical embryos, the first stage being followed by a stage of growth while new critical embryos would be continuously nucleated. In contrast, in the second case one assumes that the concentration of point defects is initially the equilibrium concentration at the growth conditions which is very low. Almost all the water would thus be incorporated as tiny clusters of water molecules too small to be detected and precipitation would occur by intercluster diffusion, the bigger clusters growing at the expense of the smaller ones which would progressively redissolve. In fact none of these models fully renders account of the experimental results. These results can only be interpreted by an intermediate situation. Water is incorporated during growth as tiny clusters and as a supersaturated concentration of point defects as well. In the quartz studied extensively in this article this concentration of point defects becomes approximately equal to the equilibrium one only at P ≈ 700 MPA, T ≈ 550°C. (Authors' abstract)

CORDIER, P. and DOUKHAN, J.C., 1988a. Water in quartz, point defects, solubility, diffusivity and influence on ductility (abst.): Chem. Geol., v. 70, p. 158. Authors at Lab. de structure & propriétés de l'état solide UA no 234 USTLFA, 59655 Villeneuve d'Ascq Cedex, France.

Water is known for a number of years to be the major impurity of both natural and synthetic quartzes. A small amount of water can affect dramatically the physical properties of the material quartz and especially its rheological behavior. This is the well known hydrolytic weakening phenomenon. Understanding the mechanism by which water defects act upon the ductility of quartz, i.e., upon the dislocation motion requires a precise knowledge of thermodynamic parameters like the nature and the equilibrium concentration of water point defects versus T and P. Furthermore, meaningful deformation experiments on well characterized wet quartz material have to be performed in T, P conditions such that the water content remains dissolved in the lattice during the experiment (ie., does not precipitate as the deformation proceeds).

We have investigated by Near Infrared Spectroscopy a variety of synthetic quartzes with various water contents. It appears that water can be incorporated either as clusters of water molecules or as a point defects solution. Convenient samples have thus been characterized for further experiments on the solubility and the diffusivity of water in quartz. We find a solubility H/Si of the order of 100 at. ppm at T = 700°C and P = 1200 MPa which drastically decreases as P is lowered. The diffusion coefficient of water in quartz has been investigated in the T range 350-1000°C. We find: $D(m^2s^{-1}) = 10^{-12} \exp(-95 \text{ kJ mole}^{-1}/RT)$.

Finally we find that water point defects associated to peaks in the vicinity of 4500 cm^{-1} strongly enhance the glide motion of dislocations when their concentration is lower or equal to the equilibrium solubility. For concentration above the solubility or for tiny water inclusions (peak in the vicinity of 5200 cm^{-1}) water precipitation occurs and an intense dislocation climb is observed. These two contrasted behaviors of the dislocations probably reflect contrasted behavior of quartz grains in crustal rocks depending upon the water content and the mode of incorporation of water in the consistent rocks. (Authors' abstract)

CORDIER, P. and DOUKHAN, J.C., 1988b. Mechanical behavior of wet quartz in T, P conditions such that the water content does not evolute during strain (abst.): Terra cognita, v. 8, p. 60. Authors at Univ. Lille, 59655 Villeneuve d'Ascq Cedex, France.

Understanding the ductile behavior of quartz in natural deformation and the influence of water on it is an important problem. Numerous experiments have been published since 25 years. However very dry quartz (natural or synthetic) is so hard that experimental deformations in Griggs type machines mostly proceed by fracturing even at very high T. In contrast wet synthetic quartz is ductile at moderate T (400 to 600°C) but water which is supersaturated in these crystals precipitates continuously during the deformation experiments. Water - more precisely its state of dispersion - has thus to be considered as a thermodynamic parameter like T and confining P and must be kept constant to get a meaningful test.

We have thus tried to measure the solubility of water in quartz as a function of T and P in performing annealings at given T and P and in controlling by TEM if water bubbles occur or not or even are redissolved. Then we have performed deformation tests on crystals with a water concentration such that no evolution of the state of water is expected. The corresponding stress-strain curves are thus representative of the rheological behavior of wet quartz in nature. (Authors' abstract)

CORDIER, P. and DOUKHAN, J.C., 1988b, Experimental investigation of the solubility of water in quartz: Consequences for plastic deformation (abst.): 12th Reunion des Sci. de la Terre, 27-29 April, 1988, Abstracts, p. 35 (in French). Authors at Lab. de structure et propriétés de l'état solide, USTLFA, 59655 Villeneuve d'Ascq Cedex, France.

Water, a common impurity in quartz, profoundly changes the mechanical properties of the mineral. Dry quartz cannot be plastically deformed, even under confining P at very high T. By contrast, synthetic quartz containing water is ductile at T > 400°C, but water, supersaturated in these crystals, separates throughout the deformation and affects the experimental data. Water (or more precisely its state of dispersion) must therefore be considered as a thermodynamic parameter like P and T, and must not undergo change during a meaningful experiment. We have attempted to determine experimentally the solubility of water in quartz by annealing wet quartz under a confining P. The presence of water bubbles was checked for by M.E.T. [i.e., TEM?]. Then we performed experiments at T and P conditions for which the water content of the crystals should not have changed during the experiment. The resulting stress-strain curves represent the intrinsic rheologic behavior of quartz containing water. (Authors' abstract, translated by C.J. Eastoe)

CORTECCI, Gianni, LATTANZI, Pierfranco and TANELLI, Giuseppe, 1988, Barite-iron oxide-pyrite deposits from Apuane Alps (northern Tuscany, Italy): Mem. Soc. Geol. It., v. 30 (1985), p. 337-345 (pub. 1988) (in English). First author at Dipart. di Sci. della Terra, Univ. di Pisa.

In the Apuane Alps area, where Pb-Zn+Ag, Hg, Fe-Cu and Fe-Mn mineralizations also occur, barite-Fe oxide-pyrite deposits are the only ones which are currently exploited. They are localized in the upper part of a low-grade metamorphic silicoclastic complex (Scisti di Fornovolasco; Middle Triassic-Carnian), in particular in association with carbonatic intercalations ("Calare Metallifero"), and in the bottom of the overlying weakly metamorphic dolostones (Grezzoni:Norian). The morphology is mostly stratiform, with minor related discordant bodies (veins or irregular masses). In some stratiform bodies, a clear zoning is recognized (from bottom upwards: pyrite + barite - barite - barite + Fe oxides). Banded textures, and mega-, meso- and microscopic evidence of tectonic deformation are commonly observed.

The main ore minerals are barite, hematite, magnetite and pyrite, with minor galena, sphalerite, siderite and sulphosalts. Reconnaissance S-isotopic and fluid inclusion data are: $\delta^{34}S$ (sulphides) = -29.9 to +18.9 per mil; $\delta^{34}S$ (barite) = +6.5 to +30.8 per mil; Th of fluid inclusions in quartz and barite from 190° to 250°C, with salinities of 10% wt. NaCl eq.

The deposits, as many others in the Apuane Alps, were previously considered to be formed from hydrothermal fluid related to hypothetical early- to synkynematic granitic intrusions during the Tertiary Apenninic orogeny. We suggest on the contrary that they had a Middle Triassic sedimentary-diagenetic origin, followed by tectonization, metamorphism and partial remobilization during the Apenninic orogeny. (Authors' abstract)

COSTAGLIOLA, P., BENVENUTI, M., CORTECCI, G., LATTANZI, P. and TANELLI, G., 1988, The barite-pyrite-iron oxides deposit of M. Arsiccio, Apuane Alps (abst.): Soc. Ital. Mineral. Petrol. "SIMP Notizie," no. 7, p. 63-64 (in Italian). First author at Dip. Sci. Terra, v. La Pira 4, 50121 Firenze, Italy.

Reports microthermometric data for fluid inclusions in quartz, barite and fluorite. (P. Lattanzi)

COWAN, Jon and CANN, Joe, 1988, Supercritical two-phase separation of hydrothermal fluids in the Troodos ophiolite: Nature, v. 333, p. 259-261. Authors at Dept. Geol., The University, Newcastle-upon-Tyne NE1 7RU, UK.

The hot (350°C) black smoker springs of the ocean floor are the vents of hydrothermal systems in which cold seawater descends below the ocean floor, is heated, reacts with the host rock and is transformed into metal-bearing brine. The salinity of these brines varies between vents from ~0.7 to 2.0 times seawater salinity; this variation has been ascribed to crustal hydration, crystallization of chloride-bearing minerals or two-phase separation of seawater into components of differing salinity. Here we present fluid inclusion evidence for two-phase separation in the ancient Troodos sulphide-forming systems of Cyprus and discuss, with the $NaCl-H_2O$ system as a model, how this process could explain observed salinity variations in hydrothermal fluids. (Authors' abstract)

COWDEN, Alistair, 1988, Emplacement of komatiite lava flows and associated nickel sulfides at Kambalda, Western Australia: Econ. Geol., v.83, p.436-442. Author at Western Mining Corp., Kambalda, Western Australia 6442, Australia.

Immiscible Fe-Ni sulfide liquids were present. (E.R.)

CRAIG, H., CHOU, C.C., WELHAN, J.A., STEVENS, C.M. and ENGELKEMEIR, A., 1988, The isotopic composition of methane in polar ice cores: Science, v. 242, p. 1535-1537. First author at Isotope Lab., Scripps Inst. Oceanography, Univ. California at San Diego, La Jolla, CA 92093.

Air bubbles in polar ice cores indicate that about 300 years ago the atmospheric mixing ratio of methane began to increase rapidly. Today the mixing ratio is about 1.7 parts per million by volume, and, having doubled once in the past several hundred years, it will double again in the next 60 years if current rates continue. Carbon isotope ratios in methane up to 350 years in age have been measured with as little as 25 kilograms of polar ice recovered in 4-meter-long ice-core segments. The data show that (i) in situ microbiology or chemistry has not altered the ice-core methane concentrations, and (ii) that the carbon-14 to carbon-12 ratio of atmospheric CH_4 in ice from 100 years and 300 years ago was about 2 per mil lower than at present. Atmospheric methane has a rich spectrum of isotopic sources: the ice-core data indicate that anthropogenic burning of the earth's biomass is the principal cause of the recent $^{13}CH_4$ enrichment, although other factors may also contribute. (Authors' abstract)

CRAIG, H., HORIBE, Y. and SOWERS, T., 1988, Gravitational separation of gases and isotopes in polar ice caps: Science, v. 242, p. 1675-1678. First author at Isotope Lab, Scripps Inst. Oceanography, Univ. California at San Diego, La Jolla, CA 92093.

Atmospheric gases trapped in polar ice at the firn to ice transition layer are enriched in heavy isotopes (^{15}N and ^{18}O) and in heavy gases (O_2/N_2 and Ar/N_2 ratios) relative to the free atmosphere. The maximum enrichments observed follow patterns prediced for gravitational equilibrium at the base of the firn layer, as calculated from the depth to the transition layer and the T in the firn. Gas ratios exhibit both positive and negative enrichments relative to air: the negative enrichments of heavy gases are consistent with observed artifacts of vacuum stripping of gases from fractured ice and with the relative values of molecular diameters that govern capillary transport. These two models for isotopic and elemental fractionation provide a basis for understanding the initial enrichments of ^{13}C and ^{18}O in trapped CO_2, CH_4, and O_2 in ice cores, which must be known in order to decipher ancient atmospheric isotopic ratios. (Authors' abstract)

CRAW, D., 1987, Fluid evolution and fluid mixing in the rapidly uplifting southern Alps, Westland, New Zealand (abst.): Geol. Soc. N. Zealand Misc. Pub. 37A, Programme and Abstracts 1987 Conf. Geol. Soc. N. Zealand (unpaginated). Author at Geol. Dept., Univ. Otago, P.O. Box 56, Dunedin.

See next item.

CRAW, D., 1988, Shallow-level metamorphic fluids in a high uplift rate metamorphic belt; Alpine Schist, New Zealand: J. Metamorphic Geol., v. 6, p. 1-16. Author at Geol. Dept., Univ. Otago, Dunedin, New Zealand.

Fluids, some of which are CO_2-rich (up to 40 mol.% CO_2) and some of which are highly saline (up to 18 wt% NaCl equiv.), are trapped as fluid inclusions in quartz-calcite (± metallic minerals) veins which cross-cut the pumpellyite-actinolite to amphibolite facies rocks of the Alpine Schist. Fluids were commonly trapped as immiscible liquid-vapor mixes in quartz and calcite showing open-space growth textures. Fluid entrapment occurred at fluid P near 500 bars (possibly as low as 150 bars) at T ranging from 260 to 330°C. Saline fluids may have formed by partitioning of dissolved salts into an aqueous phase on segregation of immiscible fluids from a low-density CO_2-rich fluid. Calcite deposited by these fluids has $\delta^{13}C$ ranging from -8.4 to -11.5 and $\delta^{18}O$ from +4 to +13. Isotopic data, fluid compositions and mode of occurrence suggest that the fluids are derived from high-grade metamorphic rocks. Fluid interaction with wall-rock has caused biotite crystallization and/or recrystallization in some rocks and retrogression of biotite to chlorite in other rocks.

Fluid penetration through the rock is almost pervasive in many areas where permeability, probably related to Alpine Fault activity, has focussed fluids on a regional scale into fractured rocks. The fluid flow process is made possible by high uplift-rates (in excess of 10 mm/year) bringing host rocks near to the surface. (Author's abstract)

CRAW, D. and KOONS, P.O., 1988, Tectonically induced gold mineralization adjacent to major fault zones (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 338-343. Authors at Geol. Dept., Univ. Otago, Dunedin, New Zealand.

Along the Alpine Fault (Southern Alps, New Zealand) there has been a local increase in the near-surface geothermal gradient to ~100°C/km and the consequent formation of numerous hot springs. Abnormally high thermal gradients persist to at least 2-3 km depth. Fluid inclusion data from late-stage veins in the Waiho Valley indicate T between 280 and 330°C at about 2-3 km depth. At and below this depth CO_2-bearing, CO_2-rich, and saline fluids mixed with low-salinity water in fractures. In this mixing zone, fluid immiscibility or "boiling" of CO_2-bearing fluids occurred, resulting in separation of saline, metal-rich fluids and precipitation of quartz, calcite and metals. (From the authors' abstract)

CRERAR, D., YANG, M., VOGEL KOPLITZ, L., SUSAK, N., IRISH, D. and McCLURE, D., 1088, Electronic and Raman spectroscopy of transition metal complexes in hydrothermal solutions (abst.): Chem. Geol., v. 70, p. 159. Authors at Dept. Geol. & Geophys. Sci., Princeton Univ., Princeton, NJ 08544, USA.

Electronic optical absorption spectroscopy and Raman spectroscopy are powerful complementary techniques for studying structural and thermodynamic properties of transition metal complexes in hydrothermal systems. Ligand-field d - >d and charge transfer electronic spectra have been used by our group to study molecular structures of Fe(II), Mn(II), Co(II), Ni(II) and Cu(II) complexes in $NaCl-H_2O$ and D_2O solutions to 300°C and 11 m Cl^-. Aqueous Mn, Ni, Co and Fe species change from octahedral to tetrahedral coordination at higher T and Cl^- concentrations. At T approaching 300°C and vapor-saturated P, species of low to neutral charge and lower coordination number predominate. This is attributable to: decreased solvent dielectric constant; the high positive entropy change of the octahedral - >tetrahedral transition; decrease in ligand field stabilization energy at higher T (LFSE $\propto$ Dq $\propto$ r^{-5} cmplx). Conversely, at higher P, LFSE and dielectric constant increase, producing more highly charged species of greater coordination number. There is a possible correlation btween tetrahedral coordination and ore genesis.

Our Raman work includes first use of trifluoromethanesulfonic acid as a preferred internal standard to 300°C. Stepwise formation constants for the tetrahedral $ZnBr_n^{2-n}$(n-1,2,3,4) complexes have been derived by bandfitting and factor analysis of $ZnBr-H_2O$ spectra to 300°C. There is no evidence for O-Zn vibrations in any species except octahedral $Zn(H_2O)_6$, suggesting that water is not strongly associated with the bromo species and that the mono- and di-bromo Zn(II) complexes might be linear. Similar Raman analyses of Pb and Zn acetate solutions to 250°C indicate strong, covalent $Zn(Ac)^+$, $Zn(Ac)_{2^\circ}$, $Zn(Ac)_{3^-}$, $Pb(Ac)^+$, $Pb(Ac)_{2^\circ}$ and possibly $Pb(Ac)_{3^-}$ complexes. Stabilities of Pb species significantly exceed those of Zn. Our data suggest mono- and bi-dentate structures with -O-M-O- covalent bonds. This work, coupled with recent polarographic measurements of Pb-organic complex stabilities by R. Hennet at Princeton suggest that acetate-metal species could be significant in deep sedimentary basins. (Authors' abstract)

CROCETTI, C.A., 1985, Isotopic and chemical studies of the Viburnum Trend lead ores of southeast Missouri: PhD dissertation, Harvard Univ., 567 pp.

Pb isotope analyses of galena determined on the ion microprobe were combined with S isotope analyses done by conventional mass spectrometry and fluid inclusion leachate analyses in an effort to determine the origin of the Viburnum Trend lead ores.

Fluid inclusion leachate analyses indicate that the composition of the ore-forming fluids of the Viburnum Trend is similar to that of typical oil field brines. The relatively elevated K^+/Na^+ ratio of the ore-forming brines may be due to interaction with the granitic basement or with arkosic sediments. The Br^-/Cl^- ratio of the fluid inclusions suggests that the brines from which the octahedral galena was deposited originated as evaporated sea water, and that the brines from which the cubic galena was deposited derived much of their salinity from the dissolution of halite.

A rough correlation between the isotopic composition of Pb and S in galena persists throughout the Viburnum Trend. The isotopic data can be explained mostly in terms of the mixing of two end members. The normal Pb component in most of the galena leads has a composition that is similar to that of Pb in basinal brines. The radiogenic lead component has a composition that is consistent with a source 1.0-1.2 b.y. in age. The composition of Pb in the galena cubes may reflect the addition of dissolved Pb from earlier generations of octahedral galena. The S of both end members appears to have a marine (evaporite) sulfate origin. The age of the mineralizing event, the physical requirements for the source basin, and the chemical similarities of the ore-forming fluids to present day Arkoma Basin brines indicate that the source of the ore-forming brines was the Quachita-Arkoma Basin during the later Carboniferous to Early Permian.

The correlation of the isotopic composition of Pb and S in the galenas strongly suggests that both elements were transported together in solution. It is proposed that the S was transported in the oxidized state (i.e., $SO_4^=$) and that sulfate reduction via the oxidation of organic carbon was the mechanism of ore precipitation. (Author's abstract)

15 samples were analyzed by crushing and leaching 3 times, with analyses of each leachate for Cl, Br, SO_4, Na, K, Li, Ca, Mg, Sr, and several for Pb and Zn. Special nonelectrolytic cleaning procedures were needed for galena. (E.R.)

CROWE, D.E., NELSON, Steven, BROWN, Philip and SHANKS, W.C., III, 1988, Stable isotope and fluid inclusion investigation of massive sulfide deposits, Orca and Valdez Groups, Alaska: Evidence for syngenetic sulfide deposition (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 153. First author at Dept. Geol., Univ. Wisconsin, Madison, WI 53706.

The composition, texture, geometry, sulfur isotope signatures, and preliminary fluid inclusion signatures of five massive sulfide deposits hosted in the upper Cretaceous and lower Tertiary Orca and Valdez Groups of southcentral Alaska suggest that these deposits represent syngenetic sulfide deposition. These syngenetic sulfides (Rua Cove, Midas, Beatson, Port Fidalgo, and Duke mines) are subdivided into two groups, those proximal to mafic volcanics (primarily pillow basalt), and those hosted within flysch with no apparent mafic volcanic association.

Volcanic-associated ores (Rua Cove, Midas) are composed of pyrrhotite (po) + chalcopyrite (cp) + cubanite ± galena and pyrite (py) + cp + po ± sphalerite assemblages. Sulfur isotope values range from 1.7 to 5.5‰ (CDT). P fluid inclusions for the stock work zone underlying one of these deposits indicate salinities ranging from 1.5 to 6.5‰ NaCl eq., suggesting mixing of sea water and more saline mineralized fluids. P corrected Th indicate minimum Tt of approximately 235°C, which is consistent, albeit lower, than T observed at modern sea floor hydrothermal vents. Preservation of primary sedimentary features, the tabular geometry, and conformable footwall and hanging wall contacts also suggest syngenetic deposition. Sediment hosted ores are composed of py or py + cp. Sulfur isotope values range from 4.8 to 11.0‰ (CDT). The samples generally contain few fluid inclusions. Preservation of cross-bedding, soft-sediment deformation, and graded bedding support deposition at the sea water-sediment interface. The volcanic associated ores likely originated in an active rifting environment similar to that proposed for many other Cyprus-type deposits. However, the flysch-hosted ores represent deposition of sulfide in a rifting environment receiving considerable sediment input, similar to a modern analog such as the Gorda Ridge. (Authors' abstract)

CRYSDALE, B.L. and BARKER, C.E., 1988, Fluid inclusion and other evidence for the timing of fluid migration in the Niobrara Formation, Berthoud State 4 well, Berthoud oil field, Denver Basin, Colorado (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A228. Authors at U.S. Geol. Survey, Box 25406, M.S. 921, Denver Fed. Center, Denver, CO 80225.

Petroleum production from the Upper Cretaceous Niobrara Limestone in the Denver Basin is largely restricted to the more permeable, fractured portions of the formation. Berthoud State 4 well cores from about 880-975 m (2900-3200 ft) depth contain zoned calcite in veins filling nearly vertical fractures. Primary, two-phase oil inclusions in these veins homogenize at a mean T (Th) of about 85°C. These Th data are uncorrected for P and represent minimum rock T. Mean random vitrinite-reflectance (Rm) over this same depth interval is 0.65%. Interpretation of this Rm, using an empirical calibration with peak burial T (Tpeak), indicates that these rocks reached a Tpeak of approximately 100°C. Published clay-mineral assemblage data suggest Tpeak was at least 100°C.

Burial history reconstruction for Berthoud State 4 suggests Tpeak was reached about 70 Ma, quickly followed by T decrease due to uplift and extensive erosion. This unique burial history fixes the time of oil migration at near-maximum burial.

Is this petroleum indigenous to this type II, kerogen-rich, thermally mature Niobrara source rock? Vertical fluid flow in the Denver Basin has been restricted by impermeable Cretaceous shales, perhaps resulting in the isolation of oils generated from the Niobrara Formation. The pale-yellow fluorescence of oil inclusions in the veins, indicative of a 30 to 45° API oil, is consistent with the 40° API oil produced from the Niobrara Limestone in the Berthoud field. However, attempts to prove the Niobrara is the source of the oil are ambiguous to date. (Authors' abstract)

CRYSDALE, B.L. and BARKER, C.E., 1988b, Fluid inclusion and other evidence for the timing of fluid migration in the Niobrara Formation, Berthoud State 4 Well, Berthoud oil field, Denver Basin, Colorado: U.S. Geol. Survey Open-File Report OF 88-0643, 19 pp.

See previous item. (E.R.)

CUNNINGHAM, C.G., ASHLEY, R.P., CHOU, I.-M., HUANG, Zushu, WAN, Chaoyuan and LI, Wenkang, 1988, Newly discovered sedimentary rock-hosted disseminated gold deposits in the People's Republic of China: Econ. Geol., v. 83, p. 1462-1467. First author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092.

Yata deposit: Th for fluid inclusions in quartz are 150° to 240°C and salinities are as much as 5 eq. wt% NaCl. Getang deposit: A few preliminary fluid inclusion Th in quartz average approximately 120°C. (From the authors' text by H.E.B.)

CURTI, Enzo and LATTANZI, P., 1988, Gold mineralization in the Monte Rosa district, NW Alps (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 262-264. First author at Inst. Kristal. u. Petrogr., ETH, Zurich, Switzerland.

Quote literature data on inclusions. (E.R.)

CYGAN, G.L. and CHOU, I.M., 1988, A new experimental technique for mineral solubility and metal-chloride speciation studies at supercritical conditions: The Ni-chloride system (abst.): EOS, v.69, p.528.

DADZE, T.P. and SOROKIN, V.I., 1988, Hydrogen sulphide in water phase of system S-H_2O at 200-400°C (experimental data) (abst.): Terra cognita, v. 8, p. 184. Authors at Inst. Exper. Min., USSR Acad. Sci., Chernogolovka, Moscow, USSR.

Experimental investigation of water phase composition in the system S-H_2O gives valid information about the concentration and form of sulphur in water solutions. Solubility studies were carried out in a sampling device under isothermal-isobaric conditions. Samples were transferred into a sampler with exactly measured quantity of 10% $Cd(CH_3COO)_2$ to prevent hydrogen sulphide losses. The iodometric method was used to determine the H_2S concentration. T dependence of H_2S content in the water phase of the system $S-H_2O$ is described by the equation: $\lg m(H_2S) = 2.2727 - 2686 \cdot T^{-1} + 373730 \cdot T^{-2} \pm 0.091$. Theoretical predictions the composition of the system, as based on thermodynamic properties of water particles, have a good agreement with experiment to 320°C. (Authors' abstract)

DAI, Aihua and WANG, Henian, 1988, Experimental studies on metallogenic mechanism of Hetai gold deposit: Bull. of the Nanjing Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., v. 9, no. 3, p. 25-38 (in Chinese; English abstract). First author at IGMR, Nanjing, PRC.

According to the investigations on the composition of mineral inclusions, the ore solution of Hetai Au deposit has following characteristics: $Na^+ > K^+ > Ca^{2+} > \Sigma Fe > Cu^{2+}$, $HCO_3^- > Cl^- > F^- > \Sigma S$, $CO_2 > CH_4$. The ore-forming T of the deposit is from 200°C to 280°C. The P is $>573.3 \times 10^5$ Pa, $fO_2 = 10^{-37} - 10^{-39}$. Au, Na^+, K^+, Cl^-, F^- and other ions in the ore solution increase continuously in the processes of evolution of the ore-forming solution from early to late. Furthermore, according to these physicochemical conditions, we carried out autoclave experiments on leaching of Au of Z^c Au-bearing formation (Au = 24 ppb) by using solutions of various concentrations of $NaHCO_3$ and HCl. These show that the Sinian Au-bearing formation could provide enough materials for the Au deposits in the area through metamorphism, migmatization and granitization. Based on the paragenesis of pyrite and Au not only at Hetai but also in many other Au deposits, we also made autoclave experiments on absorbing and reducing action of pyrite on Au in Au-bearing solution, showing that pyrite and other Fe^{2+}-bearing minerals are important reducing agents for Au. The data of $\delta^{18}O$ and δD at Hetai show the ore-forming solution is the mixture of metamorphic water and meteoric water. We consider that deposit is due to the changing of T and P and the action of reducing agents is the mechanism of Au precipitation at Hetai. (Authors' abstract)

DAINES, M.J. and RICHTER, F.M., 1988a, Interconnectivity of basaltic melt in an olivine matrix (abst.): Eos, v. 69, p. 482.

See next item. (E.R.)

DAINES, M.J. and RICHTER, F.M., 1988b, An experimental method for directly determining the interconnectivity of melt in a partially molten system: Geophys. Res. Lett., v. 15, no. 13, p. 1459-1462. Authors at Dept. Geophys. Sci., Univ. Chicago, IL.

An experimental method for directly determining the degree of interconnectivity of melt in a partially molten system is discussed using an olivine-basalt system as an example. Samarium 151 is allowed time to diffuse through mixtures of olivine and basalt powder which have texturally equilibrated at 1350°C and 13 to 15 kbars. The final distribution of samarium is determined through examination of developed radiographs of the samples. A uniform distribution of samarium throughout an entire sample implies that melt is present as an interconnected network because diffusion of samarium along melt-free grain boundaries is shown not to occur in the time frame of these experiments. Quantitative determination of the degree of interconnectivity is done by establishing a one to one correspondence between a sample and its radiograph. Results suggest an interconnected melt network is established at melt fractions at least as low as 1 wt % and all melt is completely interconnected at melt fractions at least as low as 2 wt % for the system examined. (Authors' abstract)

Of pertinence to melt inclusion studies. (E.R.)

DANILOVA, V.P., KONTOROVICH, A.E., MATUKHIN, R.G., and SOKOLOV, P.N., 1988, Bitumens in Devonian rock salts of the Siberian platform: Geologiya i Geofizika, v.29, n.1, p.33-42, (in Russian; translated in Soviet Geol. and Geophys., v.29, no.1, p.28-35)

Presented for the first time is information about the content, group, and hydrocarbon compositions of bitumens identified [from inclusions] in Devonian rock salts. Features of their differences and similarities to bitumens of Cambrian salts and carbonates with $C_{org} \leq 0.1\%$ of the Siberian Platform are established. (Authors' abstract)

Elemental content (C, H, S, O+N), and gases and organic compound content are given for various salt samples. Some analyses were made of water "extracts", Br/Cl ratios, and Th ("probably ≤40°C"). (E.R.)

D'ARCO, Ph., LAGACHE, M. and PIRIOU, B., 1988, Distribution of Eu^{3+} between anorthite and hydrothermal Cl-bearing fluid at 600°C and 1.3 kbar (abst.): Chem. Geol., v. 70, p. 159. Authors at Dépt. Géol., Ecole normale supérieure 24, rue Lhomond - 75005 Paris, France.

The partition of Eu^{3+} between anorthite and hydrothermal Cl-bearing fluid has been studied as a function of the fluids' molatity[sic; r or l?] in the interval 0.5-3.0 M and the Eu-content of the mineral. The starting material is a mixture of dehydrated anorthite gel and ($CaCl_2$ + $EuCl_3$) solution. After experiment, for a duration of about 3 weeks, at 600°C and 1.3 kbar, the partition coefficient $C = (Eu/Ca)an / (Eu/Ca)_{sol}$ is calculated.

Despite some scattering, the results imply two remarks.

- The partition coefficient seems to be independent of the chlorinity of the solutions, as usually observed for homovalent exchange.

- The partition coefficient decreases from 0.8 to 0.1 as the Eu-content of anorthite increases from 0.1 to 10000 ppm.

By optical spectroscopy, only Eu^{3+} has been characterized in the solid. The ions are distributed in the four different structural Ca-sites, as well as in extended defects, such as possibly twin and cleavage planes.

Thus, the incorporation of Eu^{3+} (and possibly the other REE^{3+}) is a complex process involving numerous sites and, as a consequence, different energetics (substitution for major elements, or trapping in defects). Furthermore, the partition coefficient used may not be thermodynamically adequate. (Authors' abstract)

DARDENNE, M.A. and TOURAY, J.C., 1988, Fluorite in Brazil - Classical vein-type deposits and new types of mineralization: Chron. Rech. Min., no. 490, p. 35-46 (in French; English abstract).

With the exception of the Rio Bonito district, the fluorite deposits of Brazil lie in the southern region: Parana and Santa Catarina States. Due to the economic importance of these deposits and based on the available geological and geochemical data arising from the large exploration effort of the last years, this paper presents a preliminary classification of the fluorite deposits. The three major types are:

a) vein types of Santa Catarina and Rio de Janeiro States;
b) stratiform Proterozoic type Sete Barras (Parana, Sao Paulo States);
c) carbonatitic type Mato Preto.

The small fluorite deposits of the Bambui Group "Mississippi Valley type" and the occurrences associated with the tin granites of Goias and with the scheelite calc-silicate rocks of northeastern region are briefly mentioned. (Authors' abstract)

DARIMONT, A., 1986, Vein formation in Belgium Paleozoic from fluid inclusion studies: Ph.D. dissertation, Liège Univ., 138 pp. (in French; English abstract by the author).

The traverse veins in Belgian Paleozoic rocks present two types: the mineralized veins with calcitic gangue in Devonian and Carboniferous environments; and the unmineralized quartz veins in Cambro-Silurian and lower Devonian siliceous environments. Fluid compositions and fluid densities are determined by microthermometry and Raman microprobe. In some cases, the P-T conditions are estimated. Some quartz veins along the Ardenne anticlinal axis are formed in metamorphic P-T conditions (1.8 kbars and 400°C). The system evolves from an aqueous CO_2-rich fluid to a N_2-rich fluid, trapped at low P (<1 kbar). The Pb-Zn-Ba-F-mineralizations are formed in distinct P-T conditions: in Devonian rocks, the veins are deposited at 1000 bars and 180°C; and in Carboniferous rocks, at a P <200 bars and T <110°C. The fluid compositions are, in both cases, H_2O-NaCl-$CaCl_2$, with a salinity ~20 eq. wt.%. (Author's abstract)

DARIMONT, Anne, BURKE, Ernst and TOURET, Jacques, 1988, Nitrogen-rich metamorphic fluids in Devonian metasediments from Bastogne, Belgium: Bull. Minéral., v. 111, p. 321-330. First author at Lab. Géol. Appliquée, 45, avenue des Tilleuls, B-4000 Liège, Belgium.

Quartz veins in the low-grade Siegenian meta-arkoses and sandstones at Bastogne (Ardennes, Belgium) contain abundant fluid inclusions, some of them extremely rich in N_2. Four successive types of fluids have been identified: decrepitated inclusions with solids (chlorides, calcite, aragonite, nahcolite, ...), heterogeneous H_2O-NaCl-CO_2 fluids, pure N_2 and late, low-salinity waters. The presence of NH_4^+-rich biotite ("bastonite") in the quartz vein illustrates the interaction between minerals and N_2-rich fluids. A model of P-T evolution during vein formation is proposed, marked by a drastic P drop during the invasion of N_2-rich fluids. (Authors' abstract)

Also see Fluid Inclusion Research, v. 20, p. 88. (H.E.B.)

DARIMONT, Anne and HEYEN, Georges, 1988, Simulation of phase equilibria in the CO_2-N_2 system. Application to fluid inclusions: Bull. Minéral., v. 111, p. 179-182 (in French; English abstract). First author at Lab. Géol. Appliquée, 45 avenue des Tilleuls, B-4000 Liège, Belgium.

The P-V-T-X conditions of the phase equilibria in the CO_2-N_2 system are predicted by an equation of state below 20°C and 90 bars. Using this data, the $\bar{v}Z$ and d-Z diagrams have been constructed for the interpretation in terms of composition and density of the microthermometric parameters measured on CO_2-N_2 fluid inclusions. (Authors' abstract)

DASO, A.A.H., 1986, Geology of a metamorphosed carbonate platform: Valley of the Sahatany - Central Madagascar - A structural, petrographic, and geochemical study (abst.): PhD dissertation, Univ. Paul Sabatier, 39 Allees Jules Guesde, 31400 Toulouse, France (in French; translated by R.P. Moritz).

Quartzite-mica schist-carbonate series intruded by several plutons in Central Madagascar have been the subject of a research integrating mapping at a scale of 1:50 000, lithostratigraphic, and petrographic investigations, whole rock chemistry, and fluid inclusion studies.

Two distinct phases of metamorphism have been recognized. The first is characterized by T between 600 and 660°C (geothermometer based on the partition of Fe and Mg between garnet and biotite), and P ranging between 21.5 and 6 kbar (geobarometer based on the composition of phengites). The second is characterized by local increases of T, by enrichment of CO_2 in the fluid phase, and by retrometamorphism due to a fluid depleted in H_2O. T of this second event are estimated to be in the range of 525 to 575°C.

Fluid inclusion studies corroborate these observations. Carbonaceous, hydrocarbon-bearing, or aqueous fluids are contemporaneous with the first phase of metamorphism, and yield isochores that fit the P-T conditions defined previously. Granitic intrusions are probably responsible for the second metamorphic event. Pure CO_2 with constant densities (0.84-0.88) has been trapped at this stage, and yields isochores that can be traced through the P-T conditions of 2.2 to 3.1 kbar, and 400 to 550°C, that were defined for pegmatites in the same area (Ranorosoa, 1986). Natural decrepitation of inclusions defines a third range of P-T conditions around 1.5 kbar, and between 375 and 400°C. Fluids contemporaneous with the first stage of metamorphism are usually composed of pure CO_2, without any CH_4 or N_2. Aqueous solutions are of moderate salinity, not exceeding 25% eq. NaCl, which is relatively unexpected for lithologies with an evaporitic affinity. The aqueous solutions and the CO_2 are immiscible. (From the author's abstract)

DAVIDSON, G., LARGE, R., KARY, G. and OSBORNE, R., 1988, The BIF-hosted Starra and Trough Tank Au-Cu mineralization: A new stratiform association from the Proterozoic eastern succession of Mt Isa, Australia (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 85-90. First author at Geol. Dept., Univ. Tasmania.

An original fluid composition and T has been deduced from fluid inclusions in quartz grains in the pipes, protected from strain during metamorphism by mantles of pyrite. The P inclusions are highly saline, 42-57 wt% eq. NaCl, with Th = 186.5 - 387.9°C. S inclusions in radial decompression cracks have Th 148.2 - 345°C, salinity 31-50 wt% NaCl eq. Tm to -36.8°C suggests that $CaCl_2$ was a brine component. (From the authors' abstract)

DAVIS, D.W., LOWENSTEIN, T.K. and SPENCER, R.J., 1988, Melting behavior of fluid inclusions in laboratory-grown halite crystals in the systems $NaCl-H_2O$, $NaCl-KCl-H_2O$, and $NaCl-MgCl_2-H_2O$ (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A152. First author at Dept. Geol. Sci., S.U.N.Y., Binghamton, NY 13901.

Fluid inclusions in laboratory-grown halite crystals in the systems $NaCl-H_2O$, $NaCl-KCl-H_2O$, and $NaCl-MgCl_2-H_2O$ were studied to document their melting behavior. There are significant differences between observed melting behaviors and published equilibrium relations in these systems.

Observed T of first melting are up to 15°C below the equilibrium eutectic T due to the formation of metastable mineral assemblages. Inclusions in all three systems fail to form hydrohalite during freezing; ice and metastable halite form instead. During warming, halite and ice begin reacting to form liquid and hydrohalite in each system by -34°C, -38°C, and -44°C, respectively. A second metastable phase ($MgCl_2$*nH_2O) forms in inclusions in the system $NaCl-MgCl_2-H_2O$ (equilibrium eutectic -35°C). Recrystallization of frozen solids is clearly visible at -60°C and production of an aqueous solution is observed by -50°C. These low T are predicted for the melting of metastable $MgCl_2$*$6H_2O$ & $MgCl_2$*$8H_2O$ and for their recrystallization to the stable $MgCl_2$*$12H_2O$.

Observed final melting T of hydrohalite, ice, sylvite, and $MgCl_2$*$12H_2O$ match published equilibrium data to within 0.1°C to 2°C, depending on the phase and system.

Metastability may cause misinterpretation of FI data in natural samples. This is especially true for inclusions with first melt T below -35°C which may be erroneously interpreted as being rich in Ca^{2+}. (Authors' abstract)

DEEN, J.A., RYE, R.O. and DREXLER, J.W., 1988, Polymetallic mineralization related to magma evolution and magmatic-meteoric fluid mixing, Julcani district, Peru (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7,

p. A351. First author at Box 250, Univ. Colorado, Boulder, CO 80309.

The Julcani district consists of at least six mineralized centers in a 16 km^2 late Miocene dacitic to rhyolitic dome complex that is built on a ~ 3000 m thick Paleozoic-Mesozoic clastic sedimentary section. Mineralization occurred within 0.5 m.y. of latest dome formation and was interrupted by dike emplacement. Hydrothermal events began with fracture controlled acid-sulfate alteration zones with vuggy silica cores and successive alunite and kaolinite envelopes. This was followed by the formation of a partially overlapping major tourmaline-pyrite-bearing shatter zone and radiating dikelets. Later overlapping hydrothermal centers developed 0.5 to 2 km apart along fractures within and peripheral to this central shatter zone in adjacent domes. Generally, each center is zoned upward and outward from wolframite + Au → enargite → tetrahedrite → galena; barite is present in all zones but becomes later in the paragenesis toward the central zones. Late stage siderite and/or botryoidal pyrite overprint all zones, even at the deepest levels.

The δD, $\delta^{18}O(SO_4)$, and $\delta^{34}S$ of early alunite are -59 to -46, 14.4 to 17.1, and 22.5 to 25.2‰, respectively. Coexisting kaolinites have δD of -90 to -75‰ while coexisting pyrites have $\delta^{34}S$ of -1.2 to 1.9‰. $\Delta^{34}S$(alun-pyrite) give T of 233-263°C. $\delta D(H_2O)$ in later main stage wolframite, enargite, tetrahedrite and galena inclusion fluids range from -98 to -60‰ with largest values generally occurring at depth and in the core of the individual centers. $\delta D(H_2O)$ in late stage siderite and coexisting botryoidal pyrite inclusion fluids range from -129 to -100‰. Main stage pyrites have $\delta^{34}S$ of 0.6 to 6.2‰ while $\delta^{34}S$ of botryoidal pyrite varies from -11.2 to 24.5‰. $\delta^{18}O$ and $\delta^{34}S$ values of barite (3.4 to 15.5 and 15.5 to 256.9‰, respectively) correlate positively with the lower values occurring in the latest stages at the upper levels of the deposits. Fluid inclusion T range from >330°C in early central stages to <200°C in late central or early marginal stages.

The integrated data indicate that hydrothermal fluids were released episodically from an evolving magma(s) with mineral zonation resulting largely from the progressive decrease of fS_2 as a result of dilution and oxidation of these magmatic fluids by meteoric water at each center. As the individual systems collapsed, the fluid interface retreated into the deepest levels, depositing late stage siderite and isotopically anomalous botryoidal pyrite. (Authors' abstract)

DEINES, Peter, 1988, Causes of correlated variations in the nitrogen content and carbon and nitrogen isotopic composition of diamonds (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 38. Author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802, USA.

Variations in the nitrogen content and carbon and nitrogen isotopic composition of diamonds are in part the result of differences in the availability of the elements and their isotopic compositions in various growth environments and their temperature. They are also determined by the chemical forms in which the elements are present in the media from which the minerals grow; the availability of C-N bonds increases the nitrogen content of diamonds. Computations show that at oxygen fugacities at which carbon is stable in the system H-C-N-O the important nitrogen carriers are in decreasing importance: NH_3, HCNO, N_2, and HCN. In the presence of NH_3 nitrogen is bonded in silicate melts as Si-N. Because the relative abundances of the chemical species in which nitrogen occurs are a function of oxygen fugacity, the nitrogen content of diamonds will depend on the oxygen fugacity prevailing during their growth. The relative abundances of the carbon species varies as a function of oxygen fugacity as well. Since the isotope fractionation properties of the various carbon and nitrogen bonds differ, the carbon and nitrogen isotope fractionations between growth medium and diamond also change with oxygen fugacity. The result of these dependencies are associated variations of nitrogen content, carbon and nitrogen isotopic compositions. Example computations show that such relationships can be complex. (Author's abstract)

DEINES, Peter, HARRIS, J.W. and GURNEY, J.J., 1988, Carbon isotope and nitrogen content variations in deep diamonds (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A280. First author at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802.

Diamond suites containing eclogitic (E-Type) and peridotitic (P-Type) mineral inclusions from the Cretaceous Koffiefontein and Jagersfontein kimberlites, South Africa, were studied for $\delta^{13}C$, nitrogen content and inclusion composition. The diamond $\delta^{13}C$ frequency distributions for the two kimberlites, which are separated by only 50 km, differ. Diamonds from Koffiefontein range in $\delta^{13}C$ from -1.8 to -12.7%. vs. PDB (X = -5.4, s = ±2, n = 62), and E- and P-Type are indistinguishable in $\delta^{13}C$. The Jagersfontein diamond $\delta^{13}C$ distribution (range -3.5 to -24.4) has two modes: M_1 between -3.5 and -8.6 (X_1 = -5.3, s = ±1.2, n = 24); M_2 between -15.4 and -24.4 (X_2 = -19.2, s = ±2.3, n = 14). Most of the P-type diamonds belong to M_1. The olivines occluded by two diamonds of mode M_2 have high FeO contents (15 wt%). The majority of E-Type diamonds falls into mode M_2. Of the Koffiefontein suite three diamonds contain magnesio-wüstite and one a coexisting enstatite-magnesio-wüstite pair. The phase assemblage is taken as evidence that these diamonds grew at greater depth than normally assumed for diamond formation. $\delta^{13}C$ of these diamonds is -5, and their nitrogen content is low (3 are Type II, one Type I contains 10 ppm). In the Jagersfontein suite some eclogitic garnets have higher SiO_2 and lower Al_2O_3 contents than normal garnets in diamonds. The compositions are very similar to those of inclusions in diamonds from the Monastery Mine, South Africa. The unusual composition has been interpreted to represent a high P solid solution of pyroxene in garnet, indicating a deeper than usual origin of these diamonds also. They are uniformly depleted in ^{13}C (X = -21.2, s = ±1.9, n = 6) and low in nitrogen (5 are Type II, one Type I contains 63 ppm). The $\delta^{13}C$ range of deep diamonds in large (-5 to -24.4‰ vs. PDB) and their nitrogen content appears to be low. (Authors' abstract)

DELBOVE, F., LEBEDEV, E.B. and ROBERT, M., 1988, Experimental partitioning of Cl between aqueous fluids and aluminosilicate melts: Effect of Na, K, Ca (abst.): Chem. Geol., v. 70, p. 159. Authors at Synthese et Chimie des Min., GIS CNRS-BRGM, 1A, rue de la Férollerie, 45071 Orléans, France.

Using a radiotracer method, Cl equilibrium partitioning between silicoaluminate melts (+ H_2O) and chloride aqueous fluids was determined.

Melts were issued from gels having formulas: $NaAlSi_6O_{14}$, $KAlSi_6O_{14}$ and $Ca_{0.5}AlSi_{4.5}O_{11}$. The aqueous fluids were 0.1 to 8 m (Na, K or $Ca_{0.5}$) Cl.

Na and K were compared as to the effects of P and molality of Cl in the fluid. At 900°C, the distribution coefficient of Cl at infinite dilution, Do, is decreasing with increasing P. It is smaller for K than for Na: 3 times at 0.75 kb, 2 times at 1.5 kb, and there is practically no difference at 3 kb. With increasing molality, the relative concentration of the major oxides in the melt does not vary, but deviation relative to ideal behavior of the fluid is more pronounced for KCl than for NaCl: at 900°C, 0.75, 1.5 and 3 kb are infracritical conditions for KCl and only

0.75 and 1.5 are so for NaCl.

Ca and Na were compared as to the effects of T and molality. At 3 kb, Do is increasing and then decreasing for Na, continuously decreasing for Ca with increasing T. It is considerably larger for Ca than for Na (from 5 to 10 times). With increasing molality, the relative concentration of the major oxides vary considerably in the Ca-melt, contrary to the Na-melt: Ca↗, Si↘, while Al remains approximately constant, with a concomitant effect on the distribution coefficient of Cl and some difficulty to assess deviation to Henry's ideality. At 3 kb, 800°, 900°, 1000° and 1200° are supracritical conditions for NaCl, whereas 1400° is an infracritical one. (Authors' abstract)

DELOULE, E. and TURCOTTE, D.L., 1988, The flow of hot brines in cracks and the formation of Mississippi Valley type ore deposits (abst.): Chem. Geol., v. 70, p. 134. First author at I.P.G. Paris, 4 Place Jussieu, 75252 Paris Cedex 05, France.

The Mississippi Valley type deposits probably formed during regional ground-water flow in the surrounding sedimentary basin. Their formation required the circulation of a large volume of brines, and occurred within 1 km of the surface, with ore fluid T as high as 100 to 150°C. Recent geochemical studies on M.V.T. ore deposits have shown that deposition was discontinuous. Pulsating flows are indicated by color zoning in sphalerites (McLimans et al., 1980) and by isotopic zoning for lead and sulphur in galenas (Deloule et al., 1986). These zoning patterns are associated with dissolution features (Sverzensky[sic], 1982) and suggest high and transient fluxes of water.

Flow migration in porous media will not result in transient water fluxes, and is too slow to allow fluids to reach the surface without losing most of their heat (Cathles and Smith, 1983; Bethke, 1986). We examine the thermal evolution of solutions transported vertically by turbulent flow in fractures, and its implications for ore deposition.

The main parameter governing the flow is the fracture width, which determines the flow rate (Emerman et al., 1986), the volume and the thermal evolution of the transported fluid. Assuming local equilibrium, we trace the chemical evolution of the transported solutions, the mineral deposits associated with their cooling and the limits for fracture clogging. Then the volume of fluid expelled and the fracture width determine the location of the deposit, hence the deposit type: carbonate hosted or veins. We show that a network of thin cracks can indeed transport the volume of brines needed for the genesis of large ore deposits, such as the South East Missouri Lead District. (Authors' abstract)

DeRONDE, C.E. and BLATTNER, Peter, 1988, Hydrothermal alteration, stable isotopes, and fluid inclusions of the Golden Cross epithermal gold-silver deposit, Waihi, New Zealand: Econ. Geol., v. 83, no. 5, p. 895-923. First author at Geol. Dept., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

The Golden Cross epithermal Au-Ag deposit is located 120 km north of presently active geothermal systems of the Taupo volcanic zone in the Waihi district, Coromandel Peninsula, New Zealand. Au and Ag of economic grades (1-20 g/metric ton eq. Au over 7 million metric tons) occur in zones dominated by quartz reefs, veins, and silicified hydrothermal breccias with adularia common in these zones. The highest precious metal concentrations occur in an inferred fluid up-flow zone. Au and Ag are thought to have precipitated from cooling hydrothermal fluid largely of meteoric origin, in direct response to hydraulic fracturing and subsequent boiling.

Alteration minerals are dominated by clay, quartz, adularia, calcite, and pyrite. Hydrothermal clays show a distinct zonation with the sequence smectite, interstratified illite-smectite, illite, and chlorite corresponding to a regional increase in T with depth. Kaolinite overprints the above mineral assemblage to at least 400 m below the present ground surface. Quartz and adularia appear to be good indicators of high permeability in the past, whereas bladed calcite indicates local boiling. Fluid permeability was enhanced by repeated hydraulic fracturing. Alkali-chloride fluids with near-neutral pH were responsible for the dominant alteration described above, whereas the downward percolation of a near-surface acid-sulfate fluid, as hydrothermal activity waned, precipitated kaolinite ± hematite ± jarosite.

FI studies reveal that in main-stage quartz, type I liquid-rich inclusions with an average Th of 200°C and Tm ice of -0.5° to -1.6°C are dominant. Type I inclusions within late precipitated calcite show a Th decrease from 210° to 150°C from the center to the periphery of a large calcite body. Early(?) type Ia liquid-rich inclusions within quartz have a Th >350°C and Tm ice values of -7° to -10.2°C. Type II (vapor-rich) and type III (two-liquid, vapor-rich) inclusions within quartz with a Th 270°C have Tm ice values typically from -25.4° to -29.7°C. Type III inclusions have not previously been described from epithermal deposits in New Zealand and possibly contain organic liquid(s).

Oxygen isotopes of hydrothermal quartz exhibit distinct horizontal and vertical gradients in an east-west cross section through the deposit. The $\delta^{18}O$(SMOW) values from 7.0 to 11.7 per mil are inferred to represent a gradient in permeability (variable water/rock ratios) with higher fluid flow-through in the west of the cross section, where precious metals are concentrated. Calcite $\delta^{18}O$(SMOW) values of 5.2 to 7.8 per mil combined with FI Th are consistent with a model whereby calcite was precipitated late and over a relatively short period of time. Calculated values of $\delta^{18}O$(SMOW) of water for main-stage quartz and late-phase calcite indicate a meteoric source of -5 to -6 per mil for the hydrotheraml water. Values for $\delta^{34}S$(CDT) from hydrothermal pyrite of -1.4 to +4.8 per mil reflect, in part, late acid-sulfate fluid.

Alteration assemblages, inferred fluid compositions, T, apparent salinity, and water isotopic compositions of the Golden Cross epithermal Au-Ag deposit are analogous to those for some active geothermal systems of the Taupo volcanic zone. Golden Cross may thus have been a part of a much larger geothermal system, not unlike those of the zone today. (Authors' abstract)

DESMAISON, Y.L., NICOT, E. and GUILHAUMOU, N., 1988, Triassic rocks included in the "Terres noires" Formation: Petrographic arguments for an early halokinesis in the area of Buis-Les-Baronnies (southeast France): Bull. Soc. Géol. France, 8, v. 4, no. 5, p. 759-770 (in French; translation by J. Dubessy).

The "Terres noires" Formation, outcropping in a small anticline near Buis-Les-Baronnies (southeast France), contains bodies of "orange rocks." Their significance has been debated. These orange rocks have been interpreted as "klippes" of Triassic material or described as the product of meteoritic alteration of Callovian limestones. Their true nature, however, is of great interest owing to their geographic localization near the "Propiac" diapir, one of the rare extrusions in this basin and commonly attributed to the Alpine orogenesis. Difficulties in interpreting these rocks are due to the various geometric relations between the "orange rocks" and the black-shale environment and the tectonic disturbance of all contacts by late tectonic movements.

A petrographic study, based upon thin sections, microprobe analyses, and fluids inclusions, enabled us to recognize three main classes of rocks. Small blocks (m^3 to dm^3) usually interstratified in the black-shales, but sometimes discordant with them, are mainly fine-grained azoic dolomicritic rocks. They are correlated with similar Triassic material observed in the breccia of Propiac. Rare bipyramidal quartz found in these rocks trap three phases of hypersaline fluid inclusions in addition to halite cubes. The minimum Tt is about 180-200°C. Detrital facies, with quartz and kaolinitized white micas also exist. One rare and peculiar facies is rich in polygonal or flat clasts of microdolomite which display no specific orientation and are embedded in a matrix exhibiting an heterogranular lamination. These small rock fragments are interpreted as insoluble intraclasts developed in a cap-rock environment. Successive thin-fracture nets streak across the small lenses. Carbonate and kaolinite veins are crosscut by late coarse-grained carbonate veins. Rare, irregular and small veinlets filled with sulfur are still younger.

The second class, mainly composed of brecciated carbonate rocks rich in numerous and large quartz (2 mm to 2 cm in size), outcrops in km^3 bodies. This class is rich in various other silicates such as talc, chlorite, kaolinite, illite, potassic and sodic feldspars, hematite, and alunite. The paragenesis are different from one site to another and polyphased paragenesis is common. Numerous observations indicate the influence of an evaporitic environment: quartz exhibits hopper shapes; lenticular, discoidal or swallow-tail shapes indicate the pseudomorphic silicic replacement of gypsum crystals. Anhydrite and sometimes magnesite, as relic minerals of a previous paragenesis are detected among the numerous solid inclusions within the quartz. The fluid inclusions are hypersaline with halite and sylvite cubes. The microthermometric study constrains the minimal Tt to be ~250-350°C. The mineralogy and CO_2-N_2 vapor inclusions detected by Raman spectroscopy emphasize the analogy between these rocks and the breccias known in the diapir of Propiac.

Red and white carbonate dikes represent the third class of rocks which do not belong to the Jurassic sedimentation. They crosscut the black shales and display carbonate pseudomorphs inferred to be from gypsum. Locally, kaolinite is also present, but the chronological relations with the carbonate are still unclear. Small bipyramidal quartz, less than three millimeters in length, exhibit the same types of fluid inclusions as the quartz in the orange lenses; they differ however from bipyramidal quartz that are filled with hydrocarbons and enclosed inside geodes embayed in Callovian marls. They do not resemble the diagenetic quartz locally observed in the black shales.

All these rocks contrast with Middle to Upper Jurassic shales because the dolomitic carbonates are dominant. This lithologic property, however, suggests a common origin with the Triassic rocks of Propiac. Different thermal recrystallization conditions explain the mineralogical variations among the three classes of rocks and between them the Triassic rocks of Propiac. The common origin of all these rocks is obfuscated by their subsequent story. The relations between their field occurrences and the intensity of the recrystallizations lead to the following propositions.

1) The small lenses and the bipyramidal quartz of the black shales, the less thermally evolved material, were included early in the shales. The emplacement may have occurred during Jurassic sedimentation by means of a tectonic fault or at the time of early halokinetic movements contributing to a cap-rock growth.

2) Fluids, circulating between the sedimentary basin and the outcropping or deeply buried Triassic rocks, may have caused the partial dissolution of the Triassic rocks and the dissemination of breccia formation. The fluids possibly are coeval with cap-rock formation. They filled the veins, which were opened in the black shales probably before the Tertiary.

3) The quartz-rich breccias, underlining a probable fault along the

south edge of the anticline, are in thermal disequilibrium with their environment. These breccias arose from deeper levels and have been emplaced later than the fine-grained lenses. (Authors' abstract)

DE VIVO, B., FREZZOTTI, M.L., LIMA, A. and TRIGILA, R., 1988, S [spinel]-lherzolite nodules from Oahu island (Hawaii): Petrology, fluid inclusions and thermodynamic calculations bearing on the magma ascent pattern (abst.): Kagoshima Int'l. Conf. on Volcanoes Abstracts, p. 256. First author at Dip. di Geofis. e Vulcanol., Univ. Napoli, Italy.

Studies of xenoliths in Hawaiian lavas provide a valuable clue to understand the magmatic processes giving origin to the Hawaiian volcanoes and the nature of the underlying crust and upper mantle. The studied xenoliths occur in the olivine nephelinites of the Koolau shield in the southeastern part of Oahu. They are basically represented by spinel lherzolites, but dunites, pyroxenites, minor plagioclase + spinel lherzolites, orthopyroxenites and olivine gabbros are also present. The spinel lherzolite xenoliths consist of olivine, orthopyroxene, clinopyroxene and spinel in the following proportions: ol (50-60%), opx (20-30%), cpx (10-15%), spl (tr.-5%). The overall textures range from porphyroclastic to allotriomorphic granular; 120° triple point junctions are usual. Olivines (fo 86-90) and orthopyroxenes (en 88-90) are remarkably homogenous in composition; the clinopyroxenes are Cr-diopside; spinel has a variable Cr content (Cr/Cr + Al from .09 to .20) and a high Mg (Mg/Mg + Fe ratio = .75). Within all these phases are trapped fluid inclusions, frozen silicate melt and/or supercritical CO_2. Dark globules, possibly sulfide melts, have been also observed. The CO_2 inclusions, suitable for measurements of Th, are all S; the P ones decrepitated during the ascent of the host crystal, and are empty or biphase (L + V) with the vapor phase totalling 50-60% of the total volume. Utilizing opx-cpx geothermometers to get indicative values of Tt, all the measured inclusions proved to have been trapped between 11,500 and 250 bars. Major P clusters are distributed around 10,500, 8,750, 7,000, 5,500, 4,300, and 3,800 bars, corresponding to a range of depths between 39 km and 14 km, if we assume an hydrostatic P regime resulting from a liquid lava column ($d = 2.7\ g/cm^3$). These data suggest that xenolith ascent within the melt was not straightforward, at least in the range of the above P. Thermodynamic calculations, based on the P, T intersections of the isoactivity curves for diopside, enstatite and fayalite components in crystal-liquid reactions involving respectively cpx, opx, ol phenocrysts, support this finding. Other crystal-liquid reactions calculations, based on the xenolith phases interacting with the melt, i.e., to get information on the depth of provenance of spinel lherzolite nodules, still are in progress. (Authors' abstract)

DE VIVO, Benedetto, FREZZOTTI, M.L., LIMA, Annamaria and TRIGILA, Raffaello, 1988b Spinel lherzolite nodules from Oahu island (Hawaii): A fluid inclusion study: Bull. Minéral., v. 111, p. 307-319 First author at Dipart. Geofisica e Vulcanol., Largo S. Marcellino 10, 80138 Napoli, Italy.

Essentially pure CO_2 fluid inclusions have been found in orthopyroxene, clinopyroxene and olivine of 11 spinel lherzolite nodules in nepheline basalts from Pali (Koolau Range) and Salt Lake Crater, Oahu, Hawaii. Most of the inclusions occur along healed fractures (are thus S) and are often associated with different proportions of silicate glass; some contain a dark globule, probably a sulfide. They represent the coexistence of two or three immiscible fluid phases -- silicate melt, sulfide melt, and dense supercritical CO_2. Only a few, not associated with glass, are most likely P; they are generally bigger in size and show clear decrepitation phenomena. 361 S inclusions were studied; Th of vapor (V) and liquid (L) CO_2 range from

-54.2 to +31.1°C (95% Th:$L + V \rightarrow L$; 5% Th:$L + V \rightarrow V$), yielding CO_2 densities from 1.16 to 0.08 g/cm^3 with preferential distribution near 1.11, 0.96, 0.89, 0.79 and 0.74 g/cm^3.

Assuming a Tt of 1000°C, the corresponding Tp for a pure CO_2 system would lie in the range 0.2 to 11.5 kbar, i.e., a depth of 1 to 43 km. The CO_2 fluid inclusions give evidence that the spinel lherzolite nodules originate in the upper mantle and represent accidental fragments randomly sampled by the host nepheline basalt magma. The distribution of CO_2 densities reflects the succession of fracturing episodes during the ascent. (Authors' abstract)

DE VIVO, B., FREZZOTTI, M.L., LIMA, A. and TRIGILA, R., 1988, Spinel lherzolite nodules from Oahu island (Hawaii): A fluid inclusion study: Bull. Miner., v. 111, p. 307-319.

See previous item. (E.R.)

DE VIVO, B. and LIMA, A., 1988a, Geobarometry and geothermometry of volcanic xenoliths and nodules on the basis of fluid inclusion studies (abst.): Sci. Mtg. of Dipartimento di Geofisica e Vulcanol., Univ. di Napoli, Dec. 1988, p. 45-47 (in Italian).

DE VIVO, B. and LIMA, A., 1988b, Fluid inclusions in ore deposit studies and in mineral exploration (abst.): Sci. Mtg. of Dipartimento di Geofisica e Vulcanol., Univ. di Napoli, Dec. 1988, p. 48-50 (in Italian).

DE VIVO, B. and LIMA, A., 1988c, Fluid inclusions in the study of geothermal fields (abst.): Sci. Mtg. of Dipartimento di Geofisica e Vulcanol., Univ. di Napoli, Dec. 1988, p. 51-53 (in Italian).

DE VIVO, B., MAIORANI, A. and TRIGILA, R., 1987, On the origin of cordierite bearing rhyolites from Mt. S. Angelo (Lipari, Italy): Fluid inclusions and petrological studies: Per. Mineral., v. 56, p. 71-84. (Dated 1987 but actually published at the end of 1988.) First author at Dip. Geofis. Vulcanol., Largo S. Marcellino 10, 80138 Napoli, Italy.

Lava flows from Mt. S. Angelo (Lipari, Aeolian Islands, Italy), that typically contain granulite and gabbroic xenoliths and xenocrysts, have been investigated. In order to better understand the origin of the Lipari acid volcanics, we have tried to correlate silicate melt and CO_2 fluid inclusion data, petrologic evidence and constraints from thermodynamic calculations. The latter show no thermodynamic equilibrium between the liquid system and phenocrysts or xenocrysts. Only microphenocrystal phases (pl, opx) equilibrated with the melt at about 800°C and less than 1 kbar. Heating of silicate melt inclusions in cordierite shows no change at 1100°C; above 1100°C the oxidation phenomena compromise the observation of the vapor-liquid homogenization. Microprobe analyses of silicate melt inclusions give K-phonotrachytic and rhyolitic compositions. The latter are believed to be representative of volatile-rich residual melt. S CO_2 fluid inclusions in plagioclase homogenize ($L + V \rightarrow V$) from +29.8 to +28.7C, yielding densities from 0.30 to 0.33 g/cm^3, which give trapping P from 0.92 to 1.06 kbar (assuming Tt = 1000°C).

By integrating the above results with rare earth element data and ^{87}Sr/^{86}Sr isotope ratios, the Barker (1987) hypotheses on the origin of rhyolitic melt by crustal fusion or assimilation and crystal fractionation have been tested. (Authors' abstract)

DICKINSON, T., TAYLOR, G.J., BILD, R.W. and KEIL, K., 1988, Mantle metasomatism on the moon (abst.): 51st Ann. Meeting of the Meteoritical Soc., Fayetteville, AR, July 18-22, 1988, Abstracts, p. H-1 (Lunar and Planetary Inst. Contrib. 665). First author at Dept. Geol. & Inst. Meteoritics, Univ.

New Mexico, Albuquerque, NM 87131.

Apollo 15 mare basalts appear to be enriched in Ge compared to Apollo 12 basalts. KREEPy basalts and Apollo 14 aluminous mare basalts show the largest enrichments in Ge, by factors of 10 to 300.

Halogen-rich solutions, originating from outgassing of the lunar interior, may have permeated the mantle, preferentially leaching material from the surrounding rocks. These halogen-rich fluids would have come into contact with the more siliceous and Na, K-rich magmas in the upper mantle. (From the authors' abstract by E.R.)

DICKSON, F.W. and RYTUBA, J.J., 1988, Transport and deposition of gold and associated substances at the Carlin gold deposit, Nevada, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 728. First author at PRC, Inc., Dept. Geol. Sci., Mackay Sch. Mines, Univ. Nevada.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 90-91, 1987. (E.R.)

DILL, H., 1988, Geologic setting and age relationship of fluorite-barite mineralization in southern Germany with special reference to the Late Paleozoic unconformity: Mineral. Deposita, v. 23, p. 16-23. Author at Geol. Survey of Lower Saxony, Continental Deep Drilling Programme of the Fed. Republic of Germany, Project Management, Stilleweg 2, D-3000 Hanover 51.

The author integrates previously published fluid inclusion data with other geological, mineralogical, and chemical data. (H.E.B.)

DILLES, J.H. and EINAUDI, M.T., 1988, Alternative sources of metals and fluids in the Yerington porphyry copper district, Nevada (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 39. First author at Geol. Dept., Oregon State Univ., Corvallis, OR 97331, USA.

Field and geochemical data from fresh and hydrothermally altered rocks of the Yerington batholith provide evidence for both magmatic and wall rock sources of Cu and ore fluids. A magmatic source for Cu and high-salinity ore fluids is supported by (1) spatial/temporal association of ore with emplacement of granite porphyry dikes that emanate from an underlying granite cupola; (2) vein quartz containing high salinity fluid inclusions that homogenize at 200-550°+C; (3) coincidence of ore zones and early potassic alteration (hbl → bio) characterized by K, Cu, and S addition and Ca removal; (4) Cu depletion of mineralizing granite relative to early phases of the batholith (10 vs. 62 ppm); (5) similar $\delta^{18}O$ and δD of fresh granite ($\delta^{18}O$(Fsp) = +7.02‰; δD(Bio) = -85 to -88‰) and potassically altered ore ($\delta^{18}O$(Fsp) = +6.9‰, δD(Bio) = -68‰). These data suggest that dikes were emplaced upward during final stages of granite crystallization, and were followed by high-salinity, aqueous, magmatic fluids that cooled causing potassic alteration, quartz veins and Cu-Fe-S mineralization.

Non-magmatic fluids caused sodic-calcic alteration (Oligo-Act-Qtz-Sphene), which developed synchronously with but lateral to and deeper than potassic alteration. High-salinity fluids altered the rocks at -400°C by Na addition and K, Fe and Cu removal. Altered rock has -11 ppm Cu, $\delta^{18}O$(Fsp) = +6.8‰, and δD(Act) = -67‰. These data are consistent with a non-magmatic origin of altering fluids (saline formation waters?), which circulated up a T gradient into the Yerington batholith at 4-6 km depth. Low Cu contents in sodic-calcic alteration probably result from destruction of Cu-bearing mafic phases (hbl, bio, mgt). Alteration removed as much as 50 ppm Cu from ~8 km^3 of the Yerington batholith around the Ann-Mason porphyry deposit and may have provided up to 30% of Cu deposited (>495 M tons of 0.4% Cu). However, mass balance indicates that external sources of Cu and ore fluids were subordinate to magmatic sources. (Authors' abstract)

DINGWELL, D.B., 1988, The structures and properties of fluorine-rich magmas: A review of experimental studies, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 1-12.

DINGWELL, D.B. and LUTH, R.W., 1988, The effect of fluorine on the viscosity of diopside liquid: Carnegie Inst. Washington Ann. Rept. Director 1987/1988, p. 35-40.

DISNAR, J.R., GAUTHIER, B., CHABIN, A. and TRICHET, J., 1986, Early biodegradation of ligneous organic materials and its relation to ore deposition in the Trèves Zn-Pb ore body (Gard, France): Org. Geochem., v. 10, p. 1005-1013. First author at CNRS-BRGM.

Previous petrographical and geochemical studies on the organic content of mineralized and non-mineralized carbonate series in the Trèves Zn-Pb stratiform deposit led to the conclusion that ore deposition occurred during the diagenetic history of the sediments, in a mixed fresh/hydrothermal system (Gauthier and Disnar, 1984; Gauthier et al., 1985a). These circulations of fluids are probably responsible for the dolomitization of the original limestones and for the deposition of the ore through microbial activity (Gauthier, 1984; Gauthier et al., 1985b).

The occurrence of this activity is supported by the formation of two kinds of organic components which are attributable to this uncommon bioalteration process: alphatic-rich bitumen-like products and aromatic polyethers. The chemical composition of these two types of compounds suggests that they were produced from ligneous debris by (sulfate-reducing?) bacteria.

Other indications of the occurrence of a biological activity have been found in the nature and relative abundance of microbial amino compounds. However, these constituents are thought to have been introduced only recently into the sediments whereas other evidence supports the idea that ore deposition occurred before diagenesis. (Authors' abstract)

DOBBINS, R.A., MOHAMMED, K. and SULLIVAN, D.A., 1988, Pressure and density series equations of state for steam as derived from the Haar-Gallagher-Kell formulation: J. Phys. Chem. Ref. Data, v. 17, no. 1, p. 1-8.

DOE, B.R. and AYUSO, R.A., 1988, Towards a method to estimate the lead and cobalt contents of anoxic oceans (abst.): Chem. Geol., v. 70, p. 195. Authors at U.S. Geol. Survey, 104 National Center, Reston, VA 22092, USA.

Dissolved metals in sea water are often invoked as a source of metals in hydrothermal ore deposits even though modern sea water contains insufficient amounts of such elements as Pb to form even moderate-sized ore bodies. Modern ocean water is oxic, however, and anoxic or euxinic (sulfur-bearing) sources of metals remain unevaluated. Coupling elements such as Pb and Co with Mn, could enable calculation of approximate values. For example the value of Mn/Pb in Mn nodules formed in oxic water is normally X00. Mn in oxic ocean water is about 60 ng/l, Pb is less than 0.5 ng/l so Mn/Pb is also X00. Co behaves similarly. Thus some values of heavy elements/Mn in Mn deposits reflect those in ocean water. In euxinic Black Sea water, Zn and Cu decrease markedly relative to shallow oxic water. Co increases but Mn even more rapidly, so the value of Mn/Co still increases. Pb data are not available. Does Pb behave like Co or Zn and Cu? To address this question, preliminary x-ray fluorescence data on a sample from an Upper Jurassic sedimentary Mn carbonate deposit of the Chipoco Formation at the Tetzintla mine, Molango district, Hidalgo, Mexico, give a value for Mn/Pb of 7000, ten-times greater than modern ocean water. This ore is deduced by E.R. Force and W.F. Cannon to have formed from anoxic sea water and experience only early diagenetic effects. The metal/Mn value of the ore might then reflect ancient sea water values. If Mn contents of ancient anoxic oceans were similar to the present Black Sea and the Pb data are accurate, then the Upper Jurassic anoxic sea would contain Pb about 50 times modern oxic ocean water. Pb values therefore appear to parallel Co, but probably are still too low to constitute a Pb ore fluid. Verification of these results by isotope dilution are in process. (Authors' abstract)

DOLENKO, G.N., 1988, Problems of geochemistry of asthenospheric hydrocarbon fluids, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 104-112 (in Russian).

DOLGOV, Yu.A., 1988, Fundamental and applied problems of thermobarogeochemistry: Applied thermobarogeochemistry - Materials of the interdisciplinary seminar, June 2-4, 1987, Kazakh Acad. Sci., Alma-Ata, "Nauka" Pub. House, Alma-Ata, v. 1, p. 17-22 (in Russian). Author at the Inst. Geol. & Geophysics of Siberian Br. Acad. Sci. USSR, Novosibirsk, USSR.

There is no general trend toward a new theory of ore formation; the present-day situation may be called a "careful creeping" toward new ideas on migration of ore-forming fluids and location of ores. Until now the sophisticated ideas on vertical migration, ore-generating chambers, and ore fluid conduits did not get any practical support from finding such chambers or conduits in nature. The essential mode of migration of ore-forming fluids are by mechanical movement. Thermal, chemical, and electrical phenomena and mechanical migration of ore-forming fluid, with all accompanying physico-chemical changes, are connected with these mechanical movements. The development of openings in the Earth's crust is caused by tectonic movements and it stimulates the ore-forming process. The author discusses various situations during development of openings, i.e., fracture formation and contraction phenomena. Fluid inclusion studies (T, P, solution composition, volatiles presence, etc.) are useful in the evaluation of the mobilization of pore fluids. Fluid inclusions may help in distinguishing specific depths in monotonous rock series; three thermobarogeochemical studies of the Danilovskaya borehole (Transcarpathians) each gave the same profile. Other aims of thermobarogeochemistry are as follows: finding of the invariable peculiarities of thermobarograms over large areas of a rock complex, use of decrepitometry for ore- and oil-prospecting, determination of depth of ore formation and its thermogradient, determination of the optimum T of the ore formation. Decrepitation may be used for finding the "optimum interval of [temperature of] ore formation in the line of temperatures of polymorph points of pure water" or, in other words, "the polymorph groups;" this method is much faster than decrepitation[sic]. Such achievements of thermobarogeochemistry permit an approach to the general theory of endogeneous ore formation. This would need, however, "the reconstruction of our theoretical and applied works on the basis of their unity into a powerful organization of new type." Some proposals of such activity are given. (Abstract by A.K.)

DONALDSON, C.H. and HENDERSON, C.M.B., 1988, A new interpretation of round embayments in quartz crystals: Mineral. Mag., v. 52, p. 27-33. First author at Dept. Geol., Univ. St. Andrews, St. Andrews, Fife KY16 9ST.

The surfaces of quartz crystals that were partially dissolved in superheated, H_2O-saturated rhyolite melt are covered with hemispherical embayments; each embayment is judged to have formed where a gas bubble in the melt approached the crystal. 'Flux-line attack' and 'upward-drilling' of the refractory lining of glass tanks are analogous processes. As a bubble nears a dissolving solid it enters a compositional boundary layer in the melt, resulting in melt of variable surface tension surrounding the bubble. This unstable situation results in small-scale convection of the melt about the bubble (Marangoni convection) which can cause locally enhanced dissolution rate of the solid. It is suggested that this mechanism could cause round embayments to form in quartz phenocrysts in acid volcanic and sub-volcanic rocks. Criteria by which embayed phenocrysts formed by dissolution can be distinguished from those formed by unstable growth are reviewed briefly. (Authors' abstract)

DOROBEK, S.L., 1987, Petrography, geochemistry, and origin of burial diagenetic facies, Siluro-Devonian Helderberg Group (carbonate rocks), central Appalachians: The Am. Assoc. Petro. Geol. Bull., v. 71, no. 5, p. 492-514. Author at Dept. Geol., Washington State Univ., Pullman, WA 99164-2812.

Petrographic and geochemical studies of pore-filling cements and replacement products in the Helderberg Group (Upper Silurian-Lower Devonian, central Appalachians) document the diagenetic history of these rocks. Deep burial pore fluids were dilute to saline Na-Ca-Cl brines (from P fluid inclusion data) with stable isotopic compositions that probably were similar to isotopic compositions of formation waters from modern oil fields. (From the author's abstract by E.R.)

DOWLING, Kim and MORRISON, Gregg, 1988, Application of quartz textures to the classification of North Queensland gold deposits (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 272-276. Authors at James Cook Univ. of North Queensland, Townsville.

This discussion of quartz textures should be helpful to anyone working with fluid inclusions in gold quartz. (E.R.)

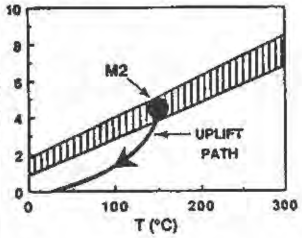
DOYLE, C.D., 1988, Prediction of the activity of FeO in multicomponent magma from known values in [SiO_2-$KAlO_2$-$CaAl_2Si_2O_8$]-FeO liquids: Geochimica Cosmo. Acta, v. 52, p. 1827-1834.

DOYLE, J.A., BODNAR, R.J. and HEWITT, D.A., 1988, Fluid inclusions from blueschist-grade metamorphic rocks: What do they tell us? (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A101. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Fluid inclusions are often used to define P-T conditions of metamorphism and to place constraints on the compositions of metamorphic fluids. Implicit in these analyses is that the inclusions have maintained constant volume and have not lost or gained components following trapping. Recent studies have shown that if the inclusion internal P exceeds the confining P during retrogression, inclusion volume may increase or fluids may be lost from the inclusion by leakage or diffusion. This is most likely to occur during uplift from very high P, low T (i.e., blueschist) metamorphic conditions.

Previous workers have determined that the late stage hydration (M2) metamorphism of interlayered cherts and basalts at the Laytonville Quarry, Mendocino County, CA, occurred at ~4.5 kbar and 150°C (see figure). Two types of inclusions were observed in quartz recrystallized during M2: small, triangular, single-phase inclusions, and larger, negative-crystal shaped inclusions, many of which contain vapor bubbles. Single-phase inclusions have high internal P at room T and decrepitate at > 170°C. Two-phase inclusions homogenize over a wide T range and often stretch or decrepitate during heating. Salinities of two-phase inclusions are ~4 wt.% NaCl eq. Evidence for CO_2 or CH_4 was not observed during crushing tests.

FI results described above are consistent with trapping at M2. Isochores bracketing M2 indicate an internal P of 1.0-1.9 kbar at 25°C (see figure). Single-phase inclusions have not reequilibrated (or have only done so partially) and have internal P >1 bar. Inclusions containing vapor bubbles have reequilibrated by stretching and/or leakage. We conclude that isochores and P-T conditions of trapping calculated from FI trapped at blueschist conditions are invalid but compositions may be determined if leakage has not occurred. (Authors' abstract)



DRUMMOND, S.E., PALMER, D.A., GIORDANO, T.H. and WESOLOWSKI, D., 1988, Hydrothermal transportation of metals via acetate complexes (abst.): Terra Cognita, v. 8, p. 183. First author at Oak Ridge Nat'l. Lab., Chem. Div. Oak Ridge, TN, USA.

A combination of potentiometric and mineral solubility studies have yielded precise measurements of the formation constants of the acetate complexes of Fe and Zn to 300°C and Al to 150°C. The potentiometric measurements employed a hydrogen-electrode concentration cell and were taken over a range of ionic strengths from 0.03 to 1.0 m and acetate concentrations from 0.001 to 0.10 m. The mono-, di- and triacetato complexes were observed for both Fe and Zn. For Fe, the log of the formation constants from 50-300°C increased from 1.2 to 3.7 for the $FeCh_3COO^+$ complex and from 2.4 to 6.8 for the $Fe(CH_3COO)_2$ complex. The $Fe(CH_3COO)_3^-$ species was observed only in the 1.0 m ionic strength experiments at 250°C and 300°C, where the log of the formation quotient varied from 3.8 to 4.7. The mono-, di- and triacetato complexes of Zn are stronger than those for Fe by factors of approximately 10, 40, and 50 respectively. A preliminary analysis of the aluminum acetate data indicate that these complexes are stronger than those for Zn. These data imply that acetate complexes can account for a significant proportion of the metals in hydrothermal and diagenetic fluids with access to organic material. (Authors' abstract)

DRURY, M.R. and van ROERMUND, H.L.M., 1988, Metasomatic origin for Fe-Ti-rich multiphase inclusions in olivine from kimberlite xenoliths: Geology, v. 16, p. 1035-1038. First author at Min. Res. Center, Res. Sch. of Chem., Australian National Univ., Canberra ACT 2601, Australia.

Because solid-solution trace elements in olivine have significant influence on upper mantle rheology, it is important to establish whether inclusions in olivine are exsolved from an intrinsic solid solution or are introduced by metasomatism. In a study of olivine in hot deformed peridotite xenoliths from kimberlites, we have found a new type of multiphase inclusion that contains Fe-Ti-rich and Si-Fe-Al-rich phases. Microstructural relations indicate that these inclusions form by a process involving metasomatic fluid infiltration along a fine network of cracks shortly before entrainment of the xenoliths, followed by crack healing during xenolith transport in the magma.

The high trace-element content of Ti, Ca, Al, and Na found in Fe-Ti-rich, hot deformed olivine is related to metasomatic enrichment that occurred shortly before kimberlite eruption. Assessment of the effects of the Fe-Ti metasomatism indicates that the Cr-C-rich inclusions found in olivine from other hot deformed xenoliths are formed by precipitation from an intrinsic solid solution in olivine that has not been affected by Fe-Ti-rich metasomatism. (Authors' abstract)

DU, Letian, 1988, H-A-C-O-N-S mantle ichor: Geotectonica et Metallogenia, v. 12, no. 1, p. 87-94 (in Chinese; English abstract). Author at Beijing Uranium Geol. Res.

Based on the diwa theory, studies of rifting, asthenosphere, anomalous mantle, depleted mantle, plume, through-magma fluid, degassing, inorganic origin of oil and gas, deep source of salt deposits, alkalic metasomatism of hydrothermal deposits, and high-T-P experiment on basalt, the author demonstrates existence of a HACONS fluid. HACONS fluid means a fluid originated in the mantle and composed of hydrogen, halogen, alkalies, carbon, oxygen, nitrogen and sulfur. The HACONS does not include aluminosilicate. Aluminosilicate results from reaction of the HACONS fluid and solid rocks. Tectonism in geosynclinal, platform and diwa stages, rifting, plate tectonics, magmatic intrusion, volcanic activity, hydrothermalism, metamorphism, hot deposition and related mineralization are manifestations of large-scaled horizontal and vertical of HACONS fluids in the asthenosphere. The asthenosphere or low-velocity layer is a HACONS-fluid-concentrated layer. [sic] (Author's abstract)

DUANE, M.J. and de WIT, M.J., 1988, Pb-Zn ore deposits of the northern Caledonides: Products of continental-scale fluid mixing and tectonic expulsion during continental collision: Geology, v. 16, p. 999-1002.

DUBESSY, Jean, PAGEL, Maurice, BENY, Jean-Michel, CHRISTENSEN, Hilbert, HICKEL, Bernard, KOSZTOLANYI, Charles, and POTY, Bernard, 1988, Radiolysis evidenced by H_2-O_2 and H_2-bearing fluid inclusions in three uranium deposits: Geochim. Cosmo. Acta, v.52, 1155-1167. First author at Centre de Recherches sur la Géologie de l'Uranium et GS CNRS-CREGU, BP 23, 54501-Vandoeuvre-lès-Nancy, Cédex, France.

H_2 with or without O_2 has been identified by Raman spectroscopy in fluid inclusions in quartz from three Precambrian U deposits: Oklo (Gabon), Rabbit Lake and Cluff Lake D (Saskatchewan, Canada). In the Oklo U deposit, heterogeneous trapping of fluids in the system H_2O-H_2-CH_4-salts is spatially associated with the natural nuclear reaction zones. At Rabbit Lake and Cluff Lake D, fluid inclusions show heterogeneous trapping of an aqueous liquid phase and a vapor phase with variable $X(O_2)/X(H_2)$ ratios always greater than one.

H_2 and O_2 formation is discussed in terms of chemical reactions indirectly induced by nuclear reactions and radiolytic processes. Numerical calculations of water radiolysis were carried out for two models: 1) water at the contact with an U oxide and 2) water inside a fluid inclusion containing either dissolved U or a small UO_2 crystal. The concentrations of O_2 and H_2 inside fluid inclusions from Rabbit Lake and Cluff Lake D deposits are consistent with the first model.

In the Oklo deposit, the H_2-bearing fluid inclusions found in the quartz and the anomalous O/C atomic ratio of organic matter from nuclear reactor zones could result from radiolysis of water and organic matter due to the fission products of the chain nuclear reactions, but α radiolysis is not definitely ruled out. (Authors' abstract)

DUBESSY, J. and POTY, B., 1988, Evidence of chemical equilibrium and disequilibrium in the C-O-H-N-S system from microRaman analysis of fluid inclusions (abst.): Chem. Geol., v. 70, p. 78. Authors at CREGU & CNRS-CREGU, BP 23, 54501 Vandoeuvre lès Nancy Cedex, France. (Continued)

Achievement of chemical equilibrium between rock-forming minerals and fluids which percolate through them is the key point for deciphering mass transfer reactions. Besides experiments which are the only way for the quantification of the kinetics law, the study of natural samples can however provide a general framework.

Redox reactions are known to be slow. Kinetics of homogeneous and heterogeneous equilibria in the C-O-H-N-S system is still poorly known. Analysis of molecular species from fluid inclusions of the C-O-H-N-S system by microRaman spectrometry gives some constraints on the minimum T required for achievement of chemical equilibrium:

1) graphite-fluid equilibrium is achieved in hydrothermal systems at T higher than 400°C. However, the reactivity of graphite to sulfate-bearing fluids can occur till 200-250°C as shown by the study of graphite alteration in Saskatchewan.

2) the redox state of the fluid is controlled by the $CO_2 + 4H_2 <-> CH_4 + 2H_2O$ equilibrium till 350°C. Below 300°C, this equilibrium does not work any more. The sulfur fugacity is controlled till 350°C by the equilibrium $CO_2 + 4H_2S <-> CH_4 + 2H_2O + 2S_2$ and fixes the pyrrhotite composition as shown on the W Salau deposit.

3) H_2-O_2-bearing fluid inclusions associated with two uranium deposits show the efficiency of radiolytic processes and the preservation of these nonequilibrium compositions at T up to 200°C.

It is emphasized that the kinetics of redox reactions in the C-O-H-N-S system is a critical parameter, which fixes partly the transport and deposition of metals by fluids, since it controls the redox state and the static dielectric constant of the fluid. (Authors' abstract)

DUBESSY, J., POTY, B. and RAMBOZ, C., 1988, Advances in fluid geochemistry based on micro-Raman spectrometric analysis of fluid inclusions: Geol. Soc. India Memoir 11, p. 125-147. First author at CREGU, GS-CNRS-CREGU, B.P. 23-54501-Vandoeuvre-Cedex, France.

The first part of this paper focuses on the analysis of fluid inclusions by micro-Raman spectrometry. SO_4^{2-} is the only polyatomic anion identified by this technique. Identification of the main monoatomic ion can be inferred from the Raman spectrum of its corresponding salt hydrate which nucleates under cooling. Gas analysis is the most fruitful field of application of micro-Raman spectrometry. Different sources of errors in the reconstruction of bulk V-X properties of gas-bearing fluid inclusions are discussed.

Geochemical constraints inferred from these analysis are discussed in the second part. The V°-X° properties of fluids of the C-O-H-N-S system, measured at room T, are shown to be representative of the V-X properties of the fluid in their P-T conditions of trapping. This allows calculation of fO_2 and fS_2. The paleo-redox state of fluids associated with U, Sn, w, and Au deposits is shown to account partly for the contrasted behavior of these metals at the hydrothermal stage. It is also emphasized that gas concentration is a key parameter for metal transport and deposition properties of fluids because it controls the static dielectric constant, which constrains the ion pair stability. The origin of N_2-bearing fluids is discussed as well the redox processes associated with this gas component. Finally, H_2 and O_2-bearing fluid inclusions evidenced in three U deposits are witnesses of water radiolysis by alpha particles. (Authors' abstract)

DUFFY, C.J., ROGERS, P.S.Z. and BENJAMIN, T.M., 1987, The Los Alamos PIXE data reduction software: Nuclear Instr. & Methods., v. B22, p. 91-95.

DUJON, S.C., 1988, Hydrothermal dissolution and crystallization of feldspars. Experimental data between 500 and 800°C, 100 and 300 MPa influence of salinity and boiling (abst.): Chem. Geol., v. 70, p. 160. Author at Dépt. Géol., Ecole normale supérieure, 24, rue Lhomond, 75005 Paris, France.

Experimental exchanges between plagioclases (solid solution) and aqueous chloride solution can be expressed by the reaction 2 $NaAlSi_3O_8$ + $CaCl_2 \rightleftharpoons CaAl_2Si_2O_8$ + 2 NaCl + 4 SiO_2. This reaction is at least 100 times faster in going from the right to the left: a stationary state is reached after one week at 800°C and three weeks at 500°C. The fast reaction is enhanced by increasing P, T, dilution of the aqueous solution, and condensation (transformation of liquid plus vapor to a supercritical single phase). At 700°C condensation occurs when P increases from 100 to 200 Mpa. The influence on the reaction is then the same as the dilution of the aqueous homogeneous solution by a factor of 5.

In natural aqueous system, increase of P and T, usually linked with burial, enhances calcic metasomatism of plagioclase. Nevertheless surrection and lowering of T in a two fluid phase system near boiling may also induce such a metasomatism through fluid condensation. Dilution of connate solution by opening of the aqueous system, has the same effect. Sodic metasomatism is a much slower reaction.

In natural and experimental exchanges between alkali feldspars and Na-K aqueous solution, exchanges are ruled by P, T and fluids boiling. Dilution of homogeneous fluids has no influence, because reaction involves elements of the same valency, which is not the case in the previous study. (Author's abstract)

DURASOVA, N.A., BELYAYEV, V.K., IGNATENKO, K.I. and KRAVTSOVA, R.P., 1987, Solubility and forms of occurrence of copper in aluminosilicate melts: Geokhimiya, no. 6, p. 895-899 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 1, p. 130-134).

ĎURIŠOVÁ, Jana, 1988, Diversity of fluids in the formation of ore assemblages in the Bohemian Massif (Czechoslovakia): Bull. Minéral., v. 111, p. 477-492. Author at Geol. Survey, Malostranské nám. 19, 118 21 Praha 1, Czechoslovakia.

Fluid inclusions in minerals from various ore assemblages in the Czech part of the Bohemian Massif were studied by optical microthermometry. Sn and W vein and greisen deposits related to the early hydrothermal post-magmatic activity of Variscan granitic plutons were formed between 300 and 500°C from chloride solutions, NaCl being the main component. The presence of two unmixing fluids (low salinity ~5 wt.% NaCl eq. and brines 35-40 wt.% NaCl) is typical. CO_2 is present only in negligible amounts (a few mol. %).

Hydrothermal Pb-Zn deposits and fluorite-barite veins (without any 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 range 110-150°C, whereas polymetallic ore veins were formed at 100-280°C.

The metamorphosed ores (massive sulphide and Au deposits) contain fluids characterized by the presence of H_2O, CO_2 and CH_4. A high density of CO_2 is common (500-960 kg/m^3), and corresponding with the metamorphic conditions. A change in the fluid composition with metamorphic grade is evident. As grade decreases, the amount of CO_2 falls, methane appears and the amount of water increases. The salinity of fluids varied from 5 to 20 wt.% NaCl eq. (NaCl predominates). (Author's abstract)

EADINGTON, P.J., 1988, The solubility of cassiterite in hydrothermal solutions in relation to some lithological and mineral associations of tin ores, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 25-32. Author at CSIRO Div. Min. Physics and Min., North Ryde, N.S.W., Australia.

The hydrothermal transport and precipitation of cassiterite is influenced by geological factors through terms in the expression for the solubility of cassiterite. The solubility and hydrothermal mobility of cassiterite under reducing conditions may be approximated by the concentration of $SnCl_2^\circ$ complex, for which $\log a(SnCl_2^\circ) = \log K - 0.5 \log f(O_2) - 2pH + 2 \log a(Cl^-)$. Extrapolation from low T thermodynamic data by the method of like equal charges and using experimental log K_w values measured in 3m NaCl yields $\log K = 15.7 - 17450/T(K)$. In 3m NaCl solutions log K_w has a linear relation with 1/T to 300°C which is the limit of experimental measurements. Deviations probably occur near the critical T which for 3m NaCl solution is 580°C, and limited extrapolation beyond 300°C seems possible. (From the author's abstract by H.E.B.)

EASTEAL, A.J. and WOOLF, L.A., 1988, Viscosity of aqueous NH_4Cl and tracer diffusion coefficients of ions, water and non-electrolytes in aqueous NH_4Cl, KI, and $MgCl_2$ at 25°C: J. Solution Chem., v. 17, no. 5, p. 447-457.

EASTOE, C.J., GUILBERT, J.M. and KAUFMANN, R.S., 1988, Preliminary evidence for fractionation of stable chlorine isotopes in Mississippi Valley-type and porphyry copper hydrothermal systems (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A97. First author at Dept. Geolsci., Univ. Arizona, Tucson, AZ 85721.

Chloride from FI in hydrothermal minerals has distinctive $\delta^{37}Cl$ values spanning the range -1.1 to +0.8 per mil. In Mississippi Valley-type deposits at Elmwood-Gordonsville, Young and Sweetwater, Tennessee, brines at high $\delta^{37}Cl$ (>0 per mil) and low $\delta^{37}Cl$ (near -1 per mil) are present. High $\delta^{37}Cl$ brines may arise during diffusional concentration of formation waters, but low $\delta^{37}Cl$ brines remain unexplained. Insufficient data exist to correlate $\delta^{37}Cl$ with paragenetic stage. In porphyry copper deposits, early brines responsible for deposition of copper and molybdenum and for potassic alteration have $\delta^{37}Cl$ values as follows: -1.0 per mil (El Salvador); -0.7 (Silver Bell); -0.5 (Panguna); +0.3, +0.8 (Bingham). These values contrast with $\delta^{37}Cl$ values of late brines associated with quartz-sericite-pyrite assemblages, viz. +0.2 per mil (Silver Bell) and +0.1 (El Salvador), implying different sources of chloride in early and late hydrothermal fluids. (Authors' abstract)

EASTOE, C.J. and NELSON, S.E., 1988, A Permian Kuroko-type hydrothermal system, Afterthought-Ingot area, Shasta County, California: Lateral and vertical sections, and geochemical evolution: Econ. Geol., v. 83, p. 588-605. Authors at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

The Afterthought and smaller Kuroko deposits in the East Shasta mining district formed at the culmination of a late Permian mafic to felsic volcanic cycle. The Kuroko deposits comprise three ore types: A: banded, fine-grained sulfides and gangue; B: recrystallized, coarser grained sulfides and gangue with a consistent paragenetic sequence; and C: coarse-grained pyrite and barite. B and C appear to replace type A. The paragenetic sequence of type B implies a sequential introduction of metals in a fluid evolving toward higher H_2S activity. Cu was introduced early as chalcopyrite and bornite; later fluids altered preexisting Cu minerals rather than introducing significant new Cu. Type B fluids probably cooled from >300°C (chalcopyrite stage) to about 270°C (sphalerite + barite stage). The last type B fluids dissolved much base metal sulfide and deposited calcite, quartz, and sericite. Most sulfides have a $\delta^{34}S$ value range of 5 to 12 per mil, implying a common origin. Hydrothermal carbonates formed from fluids with $\delta^{13}C$ values from near 0 to -12 per mil, consistent with oxidation of organic C in the hydrothermal system. Hydrothermal and postore carbonates have $\delta^{18}O$ values of 17 to 19 per mil and probably equilibrated with a single fluid after the deposition of the Hosselkus Limestone. (From the authors' abstract by E.R.)

ECHOLS, T.J., 1988, Recent thermal changes in core hole 74-18, Coso geothermal system, eastern California (abst.): Eos, v. 44, p. 1481. Author at Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521.

The Coso geothermal system consists of a liquid dominated fluid hosted mainly by igneous and meta-igneous rocks. Core hole 74-18 was drilled to a total depth of 654 meters ~1 km south of the main geothermal production area. Equilibrium downhole T exhibit a steep gradient, with a T of 236°C at total depth. The hole cored two meta-diorites and a granodiorite. Based on thin section petrography and x-ray diffraction analyses of downhole samples, these rocks are correlative to units found in the Sierra Nevada 15 km to the west across the Rose Valley structural depression.

Fluid inclusions from hydrothermal quartz and calcite veins, believed to represent the most recent mineralization episodes, have average trapping T 8° to 60°C lower than present downhole T.

X-ray diffraction analyses of the accompanying alteration indicate that the trends for calcite and epidote abundances are opposite to those expected for increasing T.

The data suggest that the Coso geothermal system in the vicinity of core hole 74-18 has undergone a 8° to 60°C increase in T since the formation of the open-space-filling euhedral quartz and calcite, and that this warming has been of such short duration that the associated minerals are not yet in chemical equilibrium at the present measured downhole T. (Author's abstract)

EFIMOVA, M.I., MALAKHOV, V.V., SOLYANIK, V.A., KOMAROVA, T.N. and NAUMKIN, P.A., 1988, Temperature conditions of formation of granitoids in some ore regions of Primor'e, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 35-45 (in Russian).

EIDT, Th. and SCHWARZ, D., 1988, Brazilian emeralds and their occurrence: Carnaíba/Bahia: Z. Dt. Gemmol. Ges., v. 37, p. 31-47 (in German; English abstract).

The mining region of Carnaíba in the Brazilian state of Bahia, is considered a "classical" emerald deposit.

The paper contains: 1) a comprehensive review of the regional and local geology, 2) the geochemistry of emeralds with their types of substitution; and 3) a description of mineral inclusions and other inclusion [fluid] phenomena. (Authors' abstract)

EILON, Gad, LANG, Barbu, STARINSKY, Avraham and TOURET, Jacques, 1988, A fluid inclusion investigation of Cenomanian quartz geodes in Israel: A possible heliothermal effect: Bull. Minéral., v. 111, p. 557-566. First author at Geol. Survey Israel, 30 Malchei Israel St., Jerusalem, Israel.

Cauliflower-like quartz geodes occur in Israel in a narrow stratigraphic interval of carbonate rocks of Lower Cenomanian age. The geodes consist of an outer rim of chalcedony, an intermediate zone of milky, anhydrite-bearing quartz and a drusy quartz-central zone. Th in P aqueous fluid inclusions can reach 170°C, most frequent measurements being between 90° and 120°C. The salinity is up to 12% wt NaCl eq. The relatively high Th, which cannot be explained either by circulating hydrothermal solutions or by T increase during burial, are interpreted as being the result of heliothermal processes (surface fluid T increase, due to absorption of solar radiation). High T and salinities in the bottom of shallow basins resulted, firstly, in the deposition of anhydrite, than[sic] in its replacement by silica. This process is controlled by the inverse dependence on T of silica and anhydrite solubilities. (Authors' abstract)

EIMON, P., 1988, Epithermal systems--what they are, where they are, and why they're important: Gold Update '87-'88: Epithermal Gold, Workshop Manual, avail. at £ 12 made out to "Univ. of Southampton," from R.P. Foster, Dept. Geology, Univ. Southampton, Southampton, UK.

Emphasis was placed by Paul Eimon [in this opening talk] on the importance of understanding the hydrology of the epithermal systems and the role that fluid inclusions can play in locating the bonanza ore shoots. The importance of well-planned and carefully regulated exploration programs was discussed at length in the final presentation [on Exploration and Evaluation]. (R.P. Foster)

ELDERS, W.A. and SASS, J.H., 1988, The Salton Sea Scientific Drilling Project: J. Geophys. Res., v. 93, no. B11, p. 12,953-12,968. First author at Inst. Geophys. & Planet. Sci., Univ. California, Riverside, CA.

In March 1986 a research borehole, called the "State 2-14," reached a depth of 3.22 km in the Salton Sea geothermal system of southern California. This was part of the Salton Sea Scientific Drilling Project (SSSDP), the first major (i.e., multimillion dollar) research drilling project in the U.S. Continental Scientific Drilling Program. The principal goals of the project were to investigate the physical and chemical processes of a high-T, high-salinity, magmatically driven hydrothermal system. The borehole encountered T of up to 355°C and produced metal-rich, alkali chloride brines containing 25 wt% of total dissolved solids. The rocks penetrated exhibit metamorphism and ore genesis in action. They show a progressive transition from unconsolidated lacustrine and deltaic sediments to hornfelses, with lower amphibolite facies mineralogy, accompanied by pervasive veins containing Fe, Cu, Pb, and Zn ore minerals. The SSSDP included an intensive program of rock and fluid sampling, flow testing, and downhole logging and scientific measurement. The purpose of this paper is to introduce this special section of the Journal of Geophysical Research on the SSSDP, to describe briefly the background of the project and the drilling and testing of the borehole, to summarize the initial scientific results, and to discuss how the lessons learned are applicable to future scientific drilling projects. (Authors' abstract)

ELDRIDGE, C.S. and McKIBBEN, M.A., 1988, Sulfur isotopic systematics in the Salton Sea geothermal system: A SHRIMP ion microprobe study of micron-scale $\delta^{34}S$ variations (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 40. First author at RSES, Australian Nat. Univ., Canberra, A.C.T., Australia.

The Salton Sea geothermal system is an area of hydrothermal metamorphism and ore genesis in Plio-Pleistocene deltaic-lacustrine-evaporite sediments. Metal-rich brines interact with the sediments at 250-350°C at 1-3 km depth, depositing silicate-carbonate-sulfide-oxide assemblages in vertical veins.

We determined $\delta^{34}S$ of sedimentary and hydrothermal sulfides and sulfates on a 30 μm scale to a precision of 2 permil using the SHRIMP ion microprobe. H_2S and SO_4 in coeval fluids were analyzed for $\delta^{34}S$ by conventional methods. Continued next page.

Stratiform sulfide contains 3 intergrown generations. F.g. early diagenetic pyrite ($\delta^{34}S$ -48 to -32 permil) is overgrown by c.g. late diagenetic pyrite (-9 to -15 permil), representing a change from open- to closed-system biogenic sulfate reduction. Later hydrothermal sulfides (≈ 0 permil) envelop sedimentary sulfides, but sedimentary S is not recycled into hydrothermal sulfides.

$\delta^{34}S$ of $CaSO_4$ in lacustrine evaporites ranges from 3 to 19 permil. Δ values for intergrown sedimentary pyrite and anhydrite show no trend with depth or T. The variable biogenic SO_4-H_2S fractionation appears to be preserved during rapid burial of the young sediments to at least 325°C.

$\delta^{34}S$ of vein sulfides is 0 ± 5 permil, but individual sulfide crystals are zoned in $\delta^{34}S$ by up to 10 permil over a distance of 1 mm. $\delta^{34}S$ of fluid H_2S ranges from -1 to 7 permil. $\delta^{34}S$ of fluid SO_4 ranges from 5 to 15 permil, identical to $\delta^{34}S$ of deep lacustrine evaporites. Therefore, fluid H_2S is not derived from leaching of sedimentary sulfides or from hydrothermal sulfate reduction. Fluid SO_4 and H_2S are derived from distinctly different sources.

An altered diabase sill at 3 km contains unusually light secondary pyrite (-4 to -7 permil), but is cut by veins containing hydrothermal pyrite (-1 to 2 permil). This shallow sill thus may have ingested sedimentary sulfide during emplacement, but it is also overprinted by later sulfide-depositing events.

$\delta^{34}S$ variations among minerals in sediment-hosted hydrothermal systems are very complex. Consequently, combining conventional $\delta^{34}S$ techniques with ion probe techniques can be crucial to understanding ore-forming processes. (Authors' abstract)

ELLIOTT, Scott, 1988, Linear free energy techniques for estimation of metal sulfide complexation constants: Marine Chem., v. 24, p. 203-213.

ENDERBY, J.L., 1985, Decrepitation and cathodoluminescence and their use in mineral exploration at Gwynfynydd mine: M.S. thesis, Univ. London, Imperial College.

Essentially the two relatively new methods, in terms of mineral exploration, of cathodoluminescence and decrepitation, have been used in order to determine the Au-bearing potential of barren and Au-bearing quartz veins from Gwynfynydd mine in North Wales.

The first part of the dissertation includes a historical and geological introduction to the Gwynfynydd mine, and is followed by a brief literature review on use in mineral exploration. The latter part involves microscopic, cathodoluminescence and decrepitation studies on samples taken from the Au-bearing Chidlaw Link Zone and the barren Big Lode.

Equipment for experimental decrepitation was designed, and the various problems encountered have been described, and where possible solved or suggestions given for their solution.

An attempt has been made to explain the results in terms of the fluid inclusion abundances and any other features of various scales across the veins.

The results obtained were encouraging, and it is thought that both cathodoluminescence and decrepitation have a future in the field of mineral exploration. (Author's abstract)

ERMOLAEV, N.P., IL'IN, M.I. and PAL'MOVA, L.G., 1987, Tellurides of gold and silver from black schists: Zap. Vses. Mineral. O-va, v. 116, no. 1, p. 85-93 (in Russian). Authors at Inst. Litos., Moscow, USSR.

Au and Ag tellurides from metasomatically altered terrigene C-bearing schists in association with pyrite, Au and Ag intermetallids and non-metalliferous minerals are discussed. The physical and chemical conditions of their origin are established. The studies are provided using the complex of neutron activation methods, electron microscopy, thermogeochemistry and chromatography of gas-liquid inclusions. (Authors' abstract)

Vacuum decrepitation studies on fluid inclusions indicated that the sulfides of black schists crystallized in 2 major stages: 300-320° and 260-280°; the early high-T association included quartz, albite, and pyrite (Py); with Py, quartz, feldspar, ankerite, and scheelite as the second generation. The Au and Ag tellurides crystallized during the terminal stages at 260-280°C. (C.A. 107: 43227z)

ESSENE, E.J., 1988, Critical evaluation of the pervasive CO_2 flooding model for granulites (abst.): Terra cognita, v. 8, p. 254. Author at Dept. Geol. Sci., Univ. Michigan, USA.

Flooding of the crust by mantle-derived carbon dioxide has been widely accepted as an explanation for the inferred drying of granulite facies terranes. Field obervations involving complexly interdigitated amphibolites and granulites have been regarded as definitive evidence of the flooding hypothesis. Geochemical arguments involving depletion of incompatible (LIL) trace elements have also been advanced in support of CO_2 purging. Phase equilibrium evidence for low H_2O activities (aH_2O) has been taken as a priori evidence for uniformly high CO_2 activities (aCO_2). The most widely cited evidence for the simple CO_2 flooding model is the presence of carbonic fluid inclusions in granulites that are inferred to have formed at the peak of metamorphism. However, alternative explanations for these observations must be considered before accepting the "carbonic metamorphism" model.

The carbonic fluid inclusions in granulites may have formed during late retrograde alteration due to loss of H_2O or migration of H_2 and concomitant oxidation. Lamb et al. (1986) have shown that some CO_2 inclusions could not have formed in equilibrium with the granulitic assemblage and were entrapped during retrogression at lower P-T. The experiments of Sterner & Bodnar (1988) suggest that few if any pristine fluid inclusions should survive from the peak of high grade regional metamorphism.

The field observations, LIL depletions and low aH_2O may be related to formation, introduction, removal and/or passage of anatectic melts. Calculated activities of major fluid species have substantial imprecisions derived from uncertainties in (a) thermometry, (b) anion occupancies in biotite and hornblende, (c) unknown activity/composition relations, and (d) locations of the relevant end member equilibria. The widespread occurrence of anatectic melts and dry orthogneisses in the granulite facies suggests that metamorphism occurs in the absence of a separate fluid phase. Thus aCO_2 should not be calculated from low aH_2O and $P_F = P_S$. Alternatively, fluids have diverse local origins, are strongly channelized along lithological and structural contacts, vary on the scale of m rather than tens of km, and may not be a separate phase in high grade metamorphic rocks. Evidence in support of local metamorphic complexity includes widespread preservation of meter scale gradients in various chemical potentials required by assemblages from granultie facies terranes. (Author's abstract)

ETMINAN, H., PORTER, R.G., HOFFMANN, C.F., SUN, S.S. and HENLEY, R.W., 1988, Initial studies of hydrothermal alteration, fluid inclusions and stable isotopes at Pajingo gold deposit, North Queensland (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 434-435. First author at Div. Petr. & Geochem., Bureau of Min. Resources, Geol. & Geophys., Canberra, A.C.T., Australia.

Th, freezing and stable isotope data confirm that the hydrothermal fluids at Pajingo were similar to those in the Taupo Volcanic Zone (New Zealand) or in well known epithermal districts (e.g., Tonopah, Nevada). Based on boiling point/depth relations, the depth of formation estimated from these data is 250-600 m (allowing for some overpressuring). Fluid inclusion data suggest that the hydrothermal system responsible for mineralization and alteration had a base T of at least 250°C but deposition of chalcedonic quartz probably occurred at a lower T (probably <200°C) due to cooling of vein fluid during transient boiling, followed by recrystallization to mosaic quartz. Te = ~-4°C, and Tm ice = -0.6 to -0.8°C, in part from CO_2 (estimated at xoo mg/kg) and a maximum salinity of 6600 mg/kg. (From the authors' abstract)

EVANS, J. P., 1988, Deformation mechanisms, textures, and differential stresses in faulted, semi-brittle granites revealed by etched SEM samples (abst.): EOS, v.69, p.472.

EVANS, W.C., WHITE, L.D. and RAPP, J.B., 1988, Geochemistry of some gases in hydrothermal fluids from the southern Juan de Fuca Ridge: J. Geophys. Res., v. 93, no. B12, p. 15,305-15,313. Authors at U.S. Geol. Survey, Menlo Park, CA.

Five samples of hydrothermal fluids from two vent areas on the southern Juan de Fuca Ridge were analyzed for dissolved gases. Concentrations in the end-member hydrothermal fluid of H_2 (270-527 μmol/kg), CH_4 (82-118 μmol/kg), and CO_2 (3920-4460 μmol/kg) are well above values in ambient seawater and are similar to concentrations reported for other ridge crest hydrothermal systems. The carbon isotopic ratios of the CH_4 ($\delta^{13}C$ = -17.8 to -20.8) and CO_2 ($\delta^{13}C$ = -3.6 to -4.7) suggest that at least some of the CH_4 and CO_2 in the fluids is basalt-derived. The range of $\delta^{13}C$ values for the basalt-derived CO_2 is -6.8 to -9.7, calculated by assuming conservation of recharge ΣCO_2 during hydrothermal circulation. Apparent T of equilibration between the CH_4 and the basalt-derived CO_2 range from 640°C to 750°C. Small amounts of ethane ($C_2H_6/CH_4 \approx 0.9 \times 10^{-3} - 2.2 \times 10^{-3}$), propane, and butane detected in the samples may also have formed in the basalt. One sample of almost pure (95.5%) hydrothermal fluid contained a significant fraction, up to 63% and 74%, respectively, of the recharge Ar and N_2. This suggests that the fluid has not undergone extensive vapor-liquid phase separation. (Authors' abstract)

EWERS, G.R. and SUN, S.-S., 1988, Genesis of the Red Dome deposit, northeast Queensland (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 110-115. Authors at Bureau of Min. Resources, Geol. & Geophys., GPO Box 378, Canberra, ACT, 2601.

Fluid inclusion measurements for quartz in phenocrysts and crenulate quartz layers in the rhyolites indicate salinities of 30 to 50 wt% NaCl eq. and Tt up to 700°C after P correction. P-corrected fluid inclusion Th for garnet and fluorite in the skarns are in the range 260-450°C, and salinities are 2-24 wt% NaCl eq. There is no evidence that boiling has occurred. The fluid inclusion data suggest that, with time, the skarn forming fluids were diluted. Laser Raman microprobe analysis has confirmed that calcite has been randomly trapped in some inclusions during skarn growth and veining of the rhyolites. CO_2 was not detected in fluid inclusions using the laser Raman microprobe. (From the authors' abstract)

FAIZIEV, A.R. and ISKANDAROV, F.Sh., 1987, New type of fluorite ore mineralization in the Pamirs: Dokl. Akad. Nauk Tadzh. SSR, v. 30, no. 6, p. 375-378 (in Russian).

See Fluid Inclusion Research, v. 20, p. 110. (E.R.)

FAIZIEV, A.R., ISKANDAROV, F.Sh., ZINCHUK, I.N., SUVOROV, P.K. and PULATOV, M.I., 1988, Physicochemical parameters of the formation of a silver-polymetallic mineralization in one of the deposits in Tadzhikistan, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 146-155 (in Russian).

FEDOROV, D.T., 1988, Trapping of pyrite-polymetal ores by magmatic bodies: Dokl. Akad. Nauk SSSR, v. 299, no. 2, p. 432-433 (in Russian). Author at State Univ., Moscow, USSR.

The author studied relations between sulfide ores and rhyolites and diabase dikes at the Kamysh polymetal deposit in Rudnyi Altai. Th of melt inclusions in quartz of rhyolite ranges from 1280 to 900°C. Rhyolite bears 2-7 mm large pyrite droplets that formed by melting of the trapped sedimentary sulfide. (A.K.)

FEELY, M., 1988, Thermometric analysis of fluid inclusions in the Galway granite, western Ireland - A preliminary study, in Annual Review 1988, Irish Assoc. for Econ. Geol., p. 97-100. Author at Dept. Geol., Univ. College, Galway, Ireland.

Fluid inclusion studies on the Galway granite at U.C.G. are directed towards hydrothermal alteration zones both within and around the batholith. In particular, the Mo-Cu mineralized zones at Mace and Roundstone are targetted for detailed study. Quartz and fluorite show S inclusions with Th mainly 100-300°C. Major Ca and Na, plus lesser K and Mg are indicated. (E.R.)

FEIN, J.B. and WALTHER, J.V., 1988, Experimental determination of calcite solubility in supercritical NaCl-H_2O fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A41. Authors at Dept. Geol. Sci., Northwestern Univ., Evanston, IL 60208.

In order to model mass transfer in the crust, the solubilities of rock-forming minerals must be measured and quantified thermodynamically. There is a severe lack of solubility measurements for the geologically important system calcite-NaCl-H_2O under hydrothermal conditions. In this study, an extraction-quench hydrothermal apparatus was used to measure the solubility of calcite in supercritical NaCl-H_2O fluids as a function of T and NaCl concentration. Experiments were conducted: (1) at 2 kbar, 500°C varying the NaCl concentrations between log NaCl molalities of -3.0 and -1.0; and (2) at 2 kbar with fixed NaCl concentrations, varying the T between 400°C and 600°C. The solubility of calcite increases with increasing NaCl concentration. For example, the log calcium molality in equilibrium with calcite increases from -4.0 at 2 kbar, 500°C, pure H_2O, to -3.1 at 2 kbar, 500°C, log NaCl molality = -1.6. However, with fixed NaCl concentrations, as the T increases from 400°C to ~550°C, calcite solubility decreases slightly with increasing T. Above 550°C, the solubility increases. A similar solubility minimum was noted by Malinin and Kanukov (1971) for calcite solubilities in 1 N NaCl fluids at 600 atm. The solubility behavior with T is in marked contrast to that of calcite in CO_2-H_2O fluids (Fein and Walther, 1987; Walther and Long, 1986), in which solubilities are strictly retrograde.

The experimental results may be compared with calcite solubilities predicted using thermodynamic data obtained from other solubility and electrical conductance studies. This provides a test of the accuracy of the thermodynamic database. The increase in calcite solubility with increasing NaCl concentration agrees reasonably well with the increase predicted using the published thermodynamic parameters. Therefore, at 2 kbar, 500°C, our data are consistent with the predicted speciation model.

For our experimental fluids, $CaCl^+$ is the dominant calcium aqueous species. These results allow for accurate predictions of mineral solubilities in geologic fluids that contain CO_2 and NaCl. (Authors' abstract)

FERGUSON, J., 1988, The nature and origin of light hydrocarbon gases associated with mineralization in the Northern Pennines: Marine & Petrol. Geol., v. 5, p. . Author at Dept. Geol., Imperial Coll., South Kensington, London SW7 2AY, UK.

Earlier studies have shown the occurrence of anomalous amounts of methane in rocks associated with Pb/Zn mineralization in a number of deposits in the British Isles and Europe. This has led to speculation that the gas may be originated either as a consequence of reactions involved in the mineralization process or as a result of maturation of the organic matter in the sediment or from a deep source. New data are presented showing the distribution of light hydrocarbon gases from fluid inclusions in minerals from the North and South Pennine ore fields which differ from those observed in the host rocks. Possible sources for the gases in the host rocks and the minerals are examined. Based on the close correlation between the distribution of the gases in the carbonate rocks of northern England and the conodont color alteration index map for the area, it is suggested that the anomalous amounts of methane gas in the Northern Pennine host rocks are the result of maturation prior to mineralization. The distribution of gases in the fluid inclusions in the minerals serves as a distinguishing feature, and two assemblages are recognized from the South Pennine ore field, both of which are distinct from that of the Northern Pennines. It is concluded that these gases, trapped at the time of mineralization, originate as a consequence of reactions which occurred during mineral deposition. (Author's abstract)

FERRY, J.M., 1988, Contrasting mechanisms of fluid flow through adjacent stratigraphic units during regional metamorphism, south-central Maine, USA: Contrib. Mineral. Petrol., v. 98, p. 1-12.

FIRSOV, A.P., 1988, The effect of heat expansion of the host-mineral on the determination of the P-T parameters based on inclusions of the mineral-forming medium, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 20-25 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 118. (E.R.)

FISHER, R.S. and KREITTER, C.W., 1987, Origin and evolution of deep-basin brines, Palo Duro Basin, Texas: Bur. Econ. Geol., Univ. Texas, Rept. Invest. No. 166, 33 pp.

FLETCHER, R.C., 1988, Quantitative modeling of pressure solution (abst.): EOS, v.69, p.481.

FOSTER, J.M., 1988, Geology and mineralization of the Lucky Hill Pit, Candelaria mine, Mineral County, Nevada: MS thesis, Univ. Nevada, Reno, NV, USA, 150 pp.

Indexed under "Fluid Inclusions." (E.R.)

FOLEY, N.K. and VARDIMAN, D.M., 1988, Paragenesis and mineral chemistry of ores of the Au-, Ag-, and base-metal-bearing North Amethyst property, San Juan Mountains, Colorado (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A276. First author at U.S. Geol. Survey, Reston, VA 22092.

Au-rich and adularia-sericite-type mineralization occurs near the southern margin of the San Luis caldera, at the intersection of the Equity fault and the northern extension of the Amethyst fault system. Preliminary studies (San Juan Symposiuum, GSA, v. 19, 1987) suggested that the ores represent a more Au-rich northern facies of mineralization occurring about 7 km to the south near Creede, Colo. However, textural, mineralogical, and chemical criteria indicate that there are at least two mainly coextensive, contrasting associations of mineral assemblages, separated locally by a period of major brecciation.

An older Au-bearing association consists of two fine-grained ore stages, both of which contain electrum, uytenbogaardite, tetrahedrite, Ag-sulfosalts, and Ag- and base-metal sulfides, and the assemblages: Mn-silicate/carbonate, and magnetite + hematite + quartz + pyrite. A younger crosscutting association contains calcite, adularia, fluorite, and quartz, plus the assemblages: coarse-grained base-metal sulfide and hematite + chlorite + pyrite. Quartz, Mn-rich calcite, and trace pyrite, which line late vugs may constitute a third association. Mineralization is confined primarily to steeply dipping structures in silicified rhyolite; intense sericitic alteration occurs at higher levels in the system. The ores are multiply brecciated, and vein filling locally shows sedimentary textures. Mineralogic, Pb-isotopic ($^{206}Pb/^{204}Pb$ = 18.972-19.060, $^{207}Pb/^{204}Pb$ = 15.591-15.671, $^{208}Pb/^{204}Pb$ = 37.781-37.921) and fluid inclusion (Th = 230-280°C, salinity = 8.5-11 wt.% NaCl eq.) features of the younger association are similar to those of ores of the main Creede district. In contrast, the Au and Mn-silicate assemblages of the older association are rare to absent in the main district. The two contrasting associations suggest major shifts with time in the chemistry of the mineralizing fluids, whereas changes within associations probably reflect local control within the hydrothermal system. (Authors' abstract)

FOSTER, J.M., LARSON, L.T. and NOBLE, D.C., 1988, Hypersaline and liquid CO_2-bearing fluid inclusions suggest that the Candelaria sediment-hosted Ag deposit is related to a porphyry system (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 161. Authors at Mackay Sch. Mines, Univ. Nevada-Reno, Reno, NV 89557.

Disseminated oxidized Ag ores of the Candelaria district, Mineral County, NV, are mostly restricted to calcareous shale and siltstone of the early Triassic Candelaria Fm. and overlying altered serpentinite, although economic values are locally found in granitic to dioritic dikes that cut these rocks. The dikes, ranging from hypidiomorphic granular to aplitic and porphyritic volcanic in texture, are present throughout the two mile length of known economic mineralization (mainly AgCl, Ag_2S, and Ag°). The dikes and the Candelaria Fm. were pervasively quartz-sericite altered at ca. 129 Ma (approx. coeval with Yerington). Quartz phenocrysts in altered dikes invariably contain S fluid inclusions. In some rocks these contain relatively large daughter grains of halite, commonly accompanied by sylvite and/or carbonate and sulfate? phases. Inclusions in several rocks contain a second liquid, presumably liquid CO_2.

Hypersaline fluid inclusions, particularly those with halite + sylvite, are typical of porphyry systems. The liquid CO_2-bearing inclusions indicate deposition at considerable depth (cf. Carlin). Primary tetrahedrite and jamesonite occur with arsenopyrite, tennantite, and gersdorfite as inclusions in and masses around ubiquitous pyrite. Other primary phases include galena, stibnite, chalcopyrite, sphalerite, and pyrrhotite. In ores Ag correlates well with Au, Pb, Cu, Mn, Zn, As, and Sb. The data together suggest that Ag mineralization took place in the upper part of a large porphyry system. Later quartz veinlets closely associated with pyrite and Ag values contain only two-phase fluid inclusions that lack dms. This suggests that metals may have been reworked and/or deposited from less saline fluids that circulated during later stages of the hydrothermal system. It appears less probable that the ores were later deposited by an unrelated "epithermal" system that fortuitously developed in the same area earlier affected by the hypersaline fluids. (Authors' abstract)

FOSTER, R.P., 1988a, Archaean gold mineralization in Zimbabwe: Implications for metallogenesis and exploration (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 62-72. Author at Dept. Geol., The Univ., Southampton, SO9 5NH, UK.

Quotes literature data (Foster, 1979; Burton, 1986) on inclusions and isotopes. (E.R.)

FOSTER, R.P., 1988b, Fluid inclusion studies: J. Geol. Soc. London, v. 145, p. 137-138. Author at Dept. Geol., Univ. Southampton, Southampton SO9 5NH, UK.

A review of the meeting at the University of Southampton in December 1986; the abstracts of these papers are in Fluid Inclusion Research, v. 18. (E.R.)

FRANCE-LANORD, Christian, 1987, Thrusting, metamorphism, and magmatism in central Nepal Himalaya: H-C-O isotope study: PhD dissertation, Inst. Nat'l. Polytech. de Lorraine, France (in French; English abstract).

H-, C-, and O-isotopes studies have been applied to characterize the nature and role of the fluids associated with the High Himalaya leucogranitic magmatism, its source rocks and the Main Central Thrust (MCT). 290 isotopic analyses of whole rocks, minerals and fluid inclusions coming from the sedimentary formations beneath (Midlands) and above (Tibetan Slab: the source of the Manaslu granite) the MCT and from the Manaslu granite define some of the metamorphic and magmatic processes.

The O-isotope variations in the Midlands preclude major infiltration and circulation of fluids. As most of the rocks are very poor in C, the CO_2-rich fluids observed in inclusions were generated at a deeper level. Dehydration of the schists with 2 to 5 wt% H_2O, liberated 20 to 40% of the initial water content in the region of the MCT where metamorphism was at a maximum, and δD decreased by about 15‰. At deeper levels, near the shear zone, devolatilization was probably more intense.

For the granite, δD muscovite varies from -70 to -85‰ and $\delta^{18}O$ whole rock from 10.9 to 12.8‰. H- and O-isotope fractionations among minerals are consistent with equilibrium at high T. A few samples, especially from the Chhokang dike swarm, have $\delta D \geq -180‰$ and disequilibrium muscovite-biotite fractionations. These rare samples are related to chloritization and late exchange with meteoric waters.

Formation I gneisses of the Tibetan Slab (source of the granite) have $\delta^{18}O$ = 12 to 14.3‰, confirming its relationship with the granite. The δD values of Formation I are however about 20‰ higher than those of the granite. This difference is related to (1) magmatic degassing associated with a H-isotope fractionation, and (2) the infiltration of D-depleted fluids into the zone of anatexis. Fluids liberated from the underlying Midlands Formation, many of whose initial δD were <-80, are the probable source.

The combined chemical and isotopic (O, Sr and Nd) data indicate that the isotopic variations in the Manaslu granite were inherited from those in Formation I. In addition, these data on Formation I can be related to the nature of the sediments and, for O and Nd, to the proportions of detrital and sheet silicate minerals. (Author's abstract)

FRANCE-LANORD, Christian and SHEPPARD, S.M.F., 1988, Large scale infiltration of fluids during regional metamorphism. H and C isotope evidence from central Nepal (abst.): Chem. Geol., v. 70, p. 160. Authors at CRPG-CNRS Nancy, BP-20, 54501 Vandoeuvre, France.

Thrusting of the hot High Himalayan Crystalline Formations over unmetamorphosed Lesser Himalaya Formations (Midlands) induce a prograde and inverted metamorphism in the Midlands (Le Fort, 1975). ∂D and ∂^{13}C have been measured in various sandstones and schists of the Midland from chlorite zone (≈ 400°C) to kyanite zone (≈ 620°C) 20 km to the north and close to the MCT thrust. Whole rock ∂D values tend to increase with metamorphic grade from -104 / -66‰ in chlorite & biotite zones to -84 / -45‰ in the garnet and kyanite zones. However in the garnet & kyanite zones ∂D decreases with the fraction of the rock water contained in the biotite. This trend is consistent with distillation of H during dehydration and biotite in/chlorite out reactions. ∂^{13}C of trace graphite increases towards the MCT from ≈ -30‰ in the chlorite & biotite zones to ≈ -20‰ in the garnet and kyanite zones.

Calculated isotopic compositions of fluids in equilibrium with the rocks, taking into account metamorphic T and modal compositions are rather uniform over the profils. ∂D of water ranges from -55 to -25‰ and ∂^{13}C of CO_2 varies between -15 & -10‰. In the high grade zones these values are similar to those of water and CO_2 from fluid inclusions of quartz pods. Combined with H_2O and C mass balance, modal compositions of rocks and fluid composition, stable isotope data imply that primary values of the Midlands were ≈ -45 to -70‰ for ∂D and ≈ -30‰ for ∂^{13}C of graphite. In situ volatilization tend to decrease ∂D values of rock (≈ 15‰ for 50% dehydration). Migration of these fluids into the lower grade zone tend to decrease ∂D of these zones through exchange. Migrating CO_2 with ∂^{13}C ≈ -10‰, probably produced in deeper zones, buffers all the graphite poor rocks. (Authors' abstract)

FRANCK, E.U., 1988, Experimental determination and calculation of binary and ternary phase diagrams of aqueous fluid systems at high temperatures and pressures (abst.): Chem. Geol., v. 70, p. 161. Author at Inst. Phys. Chem., Karlsruhe Univ., 7500 Karlsruhe, BRD.

A number of phase diagrams of aqueous systems to about 400°C and 2500 bar have been determined experimentally with a "synthetic" method. These included H_2O-CO_2, H_2O-Ar, H_2O-He, H_2O-N_2, H_2O-O_2, H_2O-H_2, H_2O-CH_4 and H_2O-hexane. The three-dimensional binodal surfaces, the critical curve and supercritical excess volumes were measured. Ternary systems investigated were H_2O-N_2-Hexane and H_2O-CO_2-Benzene. -- A new equation of state with repulsion and attraction terms, based on a well defined molecular interaction model is successful to calculate the two-phase equilibrium surfaces of the binary, ternary and probably also quaternary systems. -- Another group of ternary systems investigated is of the type H_2O-Hydrocarbon-Electrolytic Salt, like H_2O-CH_4-NaCl, H_2O-C_2H_6-NaCl and H_2O-Hexane-NaCl. Small amounts of elecolyte shift the range of two-phase behavior strongly to higher T. -- Several selected data will be shown for the H_2O-NaOH system at 400°C and 400 bar over the complete composition ragne. (Author's abstract)

FRANKE, V.D., GLIKIN, A.E. and GRUNSKY, O.S., 1988, Modelling of capture of gas-liquid inclusions by acicular and tabular crystals, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 33-38 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 121. (E.R.)

FRANTZ, J.D., MAO, H.K., ZHANG, Y.G., WU, Y., THOMPSON, A.C., UNDERWOOD, J.H. and GIAUQUE, R.D., 1988, Analysis of fluid inclusions by X-ray fluorescence using synchrotron radiation (abst.): Terra cognita, v. 8, p. 62-63. First author at Geophys. Lab., 2801 Upton St., N.W., Washington, DC 20008, USA.

The compositions of fluid inclusions in natural minerals provide a valuable source of information from which the conditions of formation of rock systems can be interpreted. The concentrations of trace elements and ionic complexes in the fluids within individual inclusions are especially important. Analysis by X-ray fluorescence using the X-ray Microprobe Line at the National Synchrotron Light Source at Brookhaven National Laboratory has proved to be a useful tool for this purpose. Using multilayer mirrors (Underwood et al., 1986) in conjunction with the Kirkpatrick-Baez mirror geometry (1948) a 10 KeV synchrotron X-ray beam can be focussed to a spot to 10 microns in diameter within an individual inclusion. The resulting fluorescence can then be used to determine the numbers of moles and concentrations of the elements contained in the fluid. Due to absorption, the intensity of the fluorescent radiation varies with the element analyzed, the composition of the host mineral, and the depth of the inclusion. To test the method, quartz crystals containing synthetic inclusions with known fluid compositions were analyzed. X-ray scans were made across inclusions containing calcium chloride, manganese chloride, and zinc chloride. Accurate determination of the number of picograms contained within an inclusion can be made using thin glass films of known composition as standards. Concentrations, however, are dependent on knowing the volume of the inclusions and are thus less accurate. The sensitivity of the technique for zinc, the heaviest element analyzed, was on the order of a few ppm or less for a 7 micron by 17 micron inclusion lying 75 microns below the surface of the quartz. For an inclusion at a depth of 20 microns, the sensitivity for calcium was found to be ~500 ppm. (Authors' abstract)

FRANTZ, J.D., MAO, H.K., ZHANG, Y.-G., WU, Y., THOMPSON, A.C., UNDERWOOD, J.H., GIAUQUE, R.D., JONES, K.W. and RIVERS, M.L., 1988, Analysis of fluid inclusions by x-ray fluorescence using synchrotron radiation: Chem. Geol., v. 69, p. 235-244.

See previous item. (E.R.)

FRANTZ, J.D., WU, Yan, THOMPSON, A.C., UNDERWOOD, J.H., GIAUQUE, R.D., MAO, H.-K. and ZHANG, Y.-G., 1988, Analysis of fluid inclusions by x-ray fluorescence with synchrotron radiation: Carnegie Inst. Washington Ann. Rept. Director 1987/1988, p. 62-69.

Details use of synchrotron x-ray beam, doubly-focussed,to analyze unopened inclusions in the 10-μm range for Ca, Mn, Zn. The method shows great promise. (E.R.)

FREZZOTTI, M.L., GHEZZO, Claudio and TOURET, Jacques, 1988, Fluids in the Monte Pulchiana intrusion (N Sardinia): Results on fluid inclusion study: Rendiconti della Soc. Italiana di Mineral. e Petrol., v. 43, p. 105-119. First author at Dipart. di Sci. della Terra, Siena, Italy.

The Monte Pulchiana leucogranite is one of the youngest post-tectonic shallow level Hercynian intrusions in Sardinia. The granite is a medium to coarse grained rock, consisting of quartz, microperthitic K-feldspar, sodic plagioclase and minor biotite. Within the pluton, especially in the border zones, some aplite dikes and pegmatitic pods are present. Sometimes the latter may contain euhedral quartz crystals in open vugs and cavities. Microscopic and microthermometric investigations on fluid inclusions in quartz from representative samples of granite and in one euhedral quartz from a pegmatitic vug give evidence of two fluid-rock interaction episodes. Two main types of fluids are recognized: the first one is present only in the granite, consisting of a highly saline aqueous fluid. Extremely variable NaCl content suggests oversaturation at the time of the final inclusion evolution (average salinity estimate around 30 wt.% NaCl; Th = 200°-310°C, in absence of boiling); and the second, a much less saline aqueous fluid (5 wt.% NaCl; Th = 100°-260°C), probably of meteoric origin, is present in the granite as well as in the pegmatite.

These observations are consistent with the existence, in subsolidus conditions, of a first NaCl oversaturated brine, probably of initial magmatic origin. Absence of boiling imposes a P greater than 1.2 kb for the granite's depth of emplacement. At a later stage, homogeneous low salinity fluid (probably meteoric water) invaded the pluton. A post magmatic roughly isobaric trajectory is proposed starting at the inferred conditions of the granite end of crystallization ($T \sim 700°C$; $P \sim 1.5$ kb). (Authors' abstract)

FRIEND, C.R.L., SRIKANTAPPA, C., RAITH, M. and SPIERING, B., 1988, Progressive charnockitization of a leptinite-khondalite suite from Kerala, India; evidence for formation of charnockites through decrease in fluid pressure? Discussion and reply: J. Geol. Soc. India, v. 31, no. 1, p. 166-175.

Indexed under "Fluid Inclusions." (E.R.)

FUHRMAN, M.L., FROST, B.R. and LINDSLEY, D.H., 1988, Crystallization conditions of the Sybille Monzosylenite, Laramie Anorthosite Complex, Wyoming: J. Petrology, v. 29, p. 699-729. First author at Dept. Earth & Space Sci., State Univ. New York, Stony Brook, NY 11794-2100.

The Sybille Monzosyenite, associated with the Laramie Anorthosite Complex, consists of rocks ranging in composition from monzogabbro to monzosyenite. There is a continuous range of mineral compositions with plagioclase varying from An_{45} to An_{25} and olivine from Fa_{75} to Fa_{98}. Strongly ternary (Or, Ab, An all >10 mol%) feldspars-presently mesoperthites-are found in all rock types and define a continuous trend also in the feldspar ternary system. The mineral compositions suggest that the rock types of the Sybille Monzosyenite could be part of a single differentiation sequence; contamination of the later units by assimilation of, or admixture of partial melts from, country rock is also likely. Original magmatic T of approximately 950-1050°C are indicated by estimated original compositions for pyroxenes and feldspars; P was near 3 kb, as indicated by the most magnesian olivine that coexists with quartz. Oxygen fugacity of crystallization is estimated as 1·5 to 2·0 log units below FMQ by using the displaced equilibrium: $SiO_2 + 2Fe_2TiO_4 = 2FeTiO_3 + Fe_2SiO_4$. Such oxygen fugacities are consistent with the occurrence of graphite and CO_2-rich fluid inclusions, which suggest that crystallization took place in the presence of a CO_2 vapor phase. T indicated by the present mineral assemblages show that all geothermometers used were reset during cooling, first by intergrain and then by intragrain processes. (Authors' abstract)

FURMAN, F.C., MISRA, K.C. and SASSEN, R., 1988, The New Albany Shale: Potential source of brines for the main-stage MVT mineralization in the Cave-in-Rock district, Illinois-Kentucky (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A39. First author at Dept. Geol. Sci., Univ. Tenn., Knoxville, TN 37996.

The main-stage Mississippi Valley-type (MVT) mineralization in the Cave-in-Rock (CR) district, composed predominantly of fluorite, is hosted in rocks of Mississippian age. Several lines of data suggest that the organic (2% TOC), metal-rich, thermally mature Devonian-Mississippian New

Albany Shale was the likely source of the brines that produced the CR main-stage mineralization. The solid bitumen in the CR fluorite is thermally immature crude oil that has been altered by water washing and biodegradation. Their $\delta^{13}C$ values (-28 to -30 per mil), pristane/phytane ratios (1.44-1.90) and carbon preference indices (~1) are similar to those of saturated and aromatic hydrocarbons of crude oils sourced by the New Albany Shale. Also $\delta^{34}S$ of New Albany crude oils, coincidentally, are similar to those reported for the CR ore sulfides. Further, published data show that the New Albany Shale is enriched in the same elements (F, Zn, Cu, Th) as the main-stage CR ore, and that the associated brines are similar to the ore-fluids in terms of salinity (19-21 NaCl eq. wt.%), T (~150°C), (Ca + Mg)/Na (<1), and isotope ratios (O, H, Pb, Sr).

It appears that metalliferous brines, along with hydrocarbons, were expelled from the New Albany Shale of the southern Illinois Basin into the overlying CR district during the Permian. The brine migration was episodic, as evidenced by rhythmic banding in the CR fluorite, and probably was controlled by seismic pumping along faults. (Authors' abstract)

GAFFREY, S.J., 1988, Mineralogical and chemical characterization of biogenic and nonbiogenic carbonates by VNIR spectroscopy: Amer. Chem. Soc., 196th Nat'l. Mtg., Los Angeles, CA, Sept. 25-30, 1988, Abstracts, p. 37.

Indexed under "Fluid Inclusions." (E.R.)

GALABURDA, Yu.A. and VOZNYAK, D.K., 1988, The role of CO_2 during the formation of the non-differentiated pegmatites of the Ukrainian Shield, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 79-85 (in Russian).

GALBREATH, K.C., DUKE, E.F., PAPIKE, J.J. and LAUL, J.C., 1988, Mass transfer during wall-rock alteration: An example from a quartz-graphite vein, Black Hills, South Dakota: Geochimica Cosmo. Acta, v. 52, p. 1905-1918. First author at Inst. for the Study of Min. Deposits, South Dakota Sch. Mines & Tech., Rapid City, SD 57701-3995, USA.

Mass transfer and fluid-rock interaction have been evaluated along two sample traverses in low-sillimanite grade quartz-mica schist adjacent to a synmetamorphic quartz-graphite vein. Mass balance calculations indicate that Al was essentially inert. The predominant chemical changes during wall-rock alteration were addition of B and C from the vein-forming fluid along with loss of K from the wall rocks, corresponding to precipitation of tourmaline and graphite, and the progressive destruction of microcline, biotite, and muscovite toward the vein. In addition the elements V, Cr, Cu, Zn, Pb, As, Sb, W, and Au were introduced into the country rock, whereas Si, Rb, Ba, and Cs were removed. On the basis of a constant Al reference frame, calculations indicate a net volume loss of 21-34% within one centimeter of the vein with little or no volume loss further from the vein.

Fluid-rock interaction modeling suggests that between one and four equivalent masses of fluid interacted chemically with the most altered mineral assemblages. In addition, greater than one equivalent mass of reactive fluid penetrated to distances of at least 5 cm from the vein contact. (From the authors' abstract by E.R.)

GAMMONS, C.H., SHENBERGER, D.S. and BARNES, H.L., 1988, Role of electrum in the hydrothermal transport and deposition of gold and silver (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 42. Authors at Ore Deposits Res. Sec., The Pennsylvania State Univ., University Park, PA 16802.

GAN, Guoliang, 1988, The characteristics of inclusions in minerals of the Huangsha vein-type tungsten deposit, Jiangxi: J. Guilin College of Geol., 1988, no. 2, p. 133-139 (in Chinese; English abstract). Author at Yichang Inst. Geol. & Mineral Resources, CAGS.

Inclusion studies show that there are close genetic relations between the W deposit and the granites, and the ore-forming fluids for two W veins are similar. Both trend towards low T and salinity, high H_2O concentration, low Na^+ and Ca^{2+} concentrations, high $\delta^{18}O$(quartz) and low $\delta^{18}O(H_2O)$ from early stage to late stage. In different evolutionary stages of the same mineralization period there are obvious differences in terms of type, shape, gas-liquid ratio, Th, salinity, gas-liquid composition and O, H isotopic composition. Therefore, the inclusions characteristics can be regarded as efficient marks for division of ore-forming stages and as efficient guides for prospecting. (Author's abstract)

GANEEV, I.G., 1988, The chemical composition of gas-liquid inclusions and the form of migration of mineral matter, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 167-175 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 129. (E.R.)

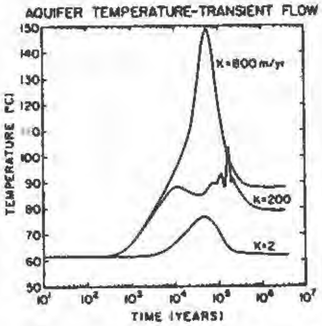
GANGOPADHYAY, S., LANDIS, C.R., PLEIL, M.W., BORST, W.L. and MUKHOPADHYAY, P.K., 1988, Time-resolved fluorescence spectroscopy of crude oils and condensates: Fuel, v. 67, p.

GARANIN, V.K., GUSEVA, Ye.V., DERGACHEV, D.V., KUDRYAVTSEVA, G.P. and ORLOV, R.Yu., 1988, Diamond crystals in garnets from weakly gneiss-textured granites: Dokl. Akad. Nauk SSSR, v. 298, no. 1, p. 190-196 (in Russian). Authors at Moscow State Univ., Moscow, USSR.

The studied samples were taken from the margin of a granite body (location not given); they consist of quartz, muscovite, garnet, plagioclase and feldspars[sic]. Garnet up to 0.5 mm in size (spessartine-almandine with small amounts of pyrope and grossular) bears cubes or rarer octahedrons, and dendritic aggregates of diamond mostly 15-20 μm in size, but sometimes up to 100 μm. Diamonds separated from garnet have yellowish color and display no luminescence in UV. Garnets bear also solid inclusions of quartz and rutile, and numerous very small G/L inclusions. P necessary for diamond crystallization was described as tangential P during boudinage tentatively determined to be ~190 kbar. Two sources of C are suggested: graphite or carbon-bearing gas-liquid fluids. (A.K.)

GARVEN, Grant, 1988, Effects of transient fluid flow on the thermal history of MVT ore mineralization (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A364. Author at Dept. Earth & Planet. Sci., The Johns Hopkins Univ., Baltimore, MD 21218.

Hydrologic modeling of brine migration in sedimentary basins has shown that regional uplift of foreland basins results in gravity-driven flow systems which are capable of forming large ore deposits of the Mississippi Valley type (Garven and Freeze, 1984). Attractive features of gravity-driven flow include the relatively large volumes of fluid transport and the elevation of fluid T in discharge areas because of the effects of forced convection on heat transport in the basin. New hydrologic models of brine migration are presented in which both the groundwater and thermal systems are allowed to evolve as a foreland basin emerges from a marine to continental state. One interesting result from the numerical experiments is that a thermal pulse is transmitted across a basin as it emerges. Fluids discharging near the up-dip edge of the basin undergo dramatic changes in T (see figure) before reaching a steady state. The hydraulic conductivity K of basin aquifers appear to have the greatest control on the magnitude of the thermal pulses, which persist for durations on the order of 10^5 years. This transient phenomenon may serve as an explanation for the chemical and thermal variations observed in MVT paragenetic and fluid inclusion data. (Author's abstract)



GAVRILOVA, S.P., GANTIMUROVA, T.P., MAKSIMYUK, I.E. and OROLMAA, D., 1988, Anomalous fluid saturation of rocks of the Erdenet copper-molybdenum ore deposit (Mongolia): Dokl. Akad. Nauk SSSR, v. 302, no. 3, p. 696-699 (in Russian). Authors at Inst. Mineral., Geokhim. Kristallokhim. Redk. Elem., Moscow, USSR.

The Erdenet Cu-Mo ore deposit of central Mongolia is localized in Late Paleozoic-Early Mesozoic volcanogenic rocks with various intrusives of two groups: (1) diorite-granodiorite-granosyenite-granite (Upper Permian) and (2) gabbro-monzonite-granosyenite. The chemical composition of the fluid component (Fc) of the ore-hosting rocks was determined; the coefficient of reduction (k) of the Fc is calculated as $K = (H_2 + CH_4 + CO + H_2S)/(H_2O + CO_2)$ and the ratio $R = (CO_2 + CO + CH_4)/(\Sigma Fc + H_2O)$ was calculated. The K and R values change in relation to the ore content of rocks. The ore-mineralized rocks exhibit anomalously high fluid saturation and a high degree of oxidation of fluids. Hydrothermal metasomatic changes induced an increase in the content of H_2O and CO_2 in the Fc. (C.A. 110: 79570g)

GAZALIYEV, I.M. and PRASOLOV, E.M., 1988, Mantle component of the gas flows in Dagestan, isotope data: Dokl. Akad. Nauk SSSR, v. 298, no. 5, p. 1218-1221 (in Russian). First author at Inst. Geol. of Dagestan Div. of Acad. Sci. USSR, Makhachkala, USSR.

Gas samples were collected in the area of Dagestan from gas flows and boreholes. Isotope analyses $^3He/^4He$ were made by mass spectrometry, chemical composition was determined by gas chromatography. Analyzed gases contain mostly helium with low $^3He/^4He$ ratio (3-7) x 10^{-8}, typical of the crustal radiogenic helium. High $^3He/^4He$ ratio of the Inkhokvara springs (35 x 10^{-8}) and Dzhani springs (14 x 10^{-8}) indicates the presence of the mantle component. These points are located at crossings of the deep-seated faults. (A.K.)

GEIGER, C.A., LANGER, K., WINKLER, B., ROSS, C.R., BELL, D.R. and ROSSMAN, G.R., 1988, The OH component in synthetic pyrope (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A224. First author at Inst. für Mineralogie und Kristal., Tech. Univ., Berlin, D-1000 Berlin 12.

A series of pyrope $Mg_3Al_2Si_3O_{12}$ single crystals was hydrothermally synthesized at $P(H_2O) = P(tot)$ at 20-50 kb and 800-1200°C. Glass, gel, and oxide mix starting materials were employed under a variety of run conditions. Product euhedral crystals from 0.03 up to 2 mm have been characterized by optical, X-ray diffraction, SEM, TEM and electron microprobe techniques. Rietveld analysis and least-squares refinement of X-ray powder data indicate a small inflation (0.002-0.003 Å) of the unit-cell dimension for hydrothermally produced pyropes above the value for strictly anhydrous pyrope grown dry from a glass (a_0 = 11.454(1)Å). This is related to OH-incorporation into the pyrope structure. Microscopic FTIR measurements in the 400-300 cm^{-1} region have been made on optically clear rim regions of thinly sliced single crystals with spatial resolution to 20 x 20 μm. In most cases only a single band at 3629 cm^{-1} has been observed. It has a full width at half height of 60 cm^{-1}. The IR and X-ray data are best interpreted as indicating that OH^- is held in the classic hydrogarnet substitution. OH concentrations were estimated from the IR data using a calibration derived from natural hydrogrossular. The maximum OH content is 0.07 wt% (expressed as H_2O) from the 1000°C, 45 kb synthesis. Syntheses at less than 40 kb typically yielded IR intensities corresponding to -0.014 wt% H_2O. Pyrope cores typically contain many tiny fluid inclusions and IR mesurement in these areas reveal a strong broad band centered around 3420 cm^{-1} related to trapped molecular H_2O. Additionally, the 3629 cm^{-1} band is more intense in the cores. The IR patterns in the OH region of the synthetic garnets do not match either natural pyrope from the Dora Maira Massif or natural pyrope-almandines from mantle sources, and are generally ten times more intense than those of natural high-Mg pyropes. (Authors' abstract)

GEISINGER, K.L., OESTRIKE, R., NAVROTSKY, A., TURNER, G.L. and KIRKPATRICK, R.J., 1988, Thermochemistry and structure of glasses along the join $NaAlSi_3O_8$-$NaBSi_3O_8$: Geochim. Cosmo. Acta, v. 52, p. 2405-2414.

GEODEKYAN, A.A., AVILOV, V.I., AVILOVA, S.D. and TROTSYUK, V.Ya., 1988, Gas-biogeochemical studies of gas craters and acoustic anomalies of Baltic Sea: Dokl. Akad. Nauk SSSR, v. 299, no. 2, p. 449-453 (in Russian). Authors at Inst. Oceanology of Acad. Sci., Moscow, USSR.

The study includes determinations CO_2, H_2, N_2 and CH_4, pertinent to composition of inclusions in diagenetic minerals. (A.K.)

GEORGE-ANIEL, B. and LEROY, J., 1987, Physico-chemical characterization of the kaolinitization in the intravolcanic deposit of Nopal I (Mexico) (abst.): Bull. de Liaison de la Soc. franc. de Min. et de Crist., v. 110, no. 5, p. 96-97 (in French). Authors at CREGU, BP 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

(...) The main ore deposition and alteration event is characterized by the formation of a pitchblende-pyrite assemblage, and the development of kaolinite over ~100 m around the mineralized chimney. ... The study of fluid inclusions associated with this kaolinitization allowed us to define with accuracy the composition of the fluids that caused the alteration (H_2O + 2.5 eq. wt % NaCl), and the T of this event (250°C). Computer simulations of the kaolinitization process (Dissol program by B. Fritz) have been carried out using the entire analytical data obtained, which are the only ones that can constrain the system. (From the authors' abstract, translated by R. Moritz)

GHAZBAN, Fereydoun, 1987, Geochemistry of carbonate-hosted Pb-Zn deposits, Baffin Island, NWT: Unpub. PhD thesis, McMaster Univ.

The Nanisivik deposits located in northern Baffin Island, are strata-bound dolostone-hosted sulfide deposits which display many similarities to Mississippi Valley-type ore deposits. Continued next page.

The sulfide mineralization is contained within the upper member of Proterozoic Society Cliffs Formation which is mainly composed of algal laminated dolostones. The host rocks are pervasively dolomitized. The Society Cliffs carbonate sequence acquired its host capability due to extensive dolomitization and accompanying karstification. This process may have also contributed to the metal content of the pore fluids. The occurrence of fracture-filling luminescent-banded dolomite cements produced by ascending warm fluids prior to and partly concurrent with sulfide occurrence have caused the occlusion of porosity.

During mineralization, host rock dissolution occurred in the ore site, indicating addition of acid to the fluids by reduction of sulfate by organic materials at the ore site and in part by sulfide precipitation. As a result, the ore occurs in space created by corrosive hydrothermal fluids and also cavities and underground channelways suggestive of karstic proceses.

White sparry dolomite, the major gangue mineral of main stage mineralization, displays a wide range in $\delta^{13}C$ indicating carbon contribution from various sources. The isotopic compositions of the dolomite gangue suggest that they were partly a by-product of dissolution-reprecipitation of dolostone host rock and partly due to sulfate reduction processes by hydrocarbons and related organic matter which contributed to the CO_2 production. The $\delta^{18}O$ for the ore dolomite spans a narrower range which is consistent with the T variations of the ore fluids during mineralization.

The stable isotopic composition of inclusion fluids of the minerals from the main stage mineralization obtained directly by crushing the minerals, do not appear to differ substantially from one another. The H and O isotope data from the fluid inclusions are consistent with derivation of metals predominantly by exchange reaction of the fluids with large volume of metalliferous sediments. This indicates that the water/rock ratio in the hydrothermal system was probably low and isotopic exchange occurred under moderate T. These data point to the similarity between the ore fluids and oil field brines. This similarity suggests that the hydrothermal Pb-Zn deposits are genetically related to oil formation and accumulation of the same age.

Based on the S isotope fractionation between coprecipitating sulfide minerals, the T of sulfide precipitation is estimated to be in a range of 90 to 250°C. These T are in accordance with data obtained by fluid inclusion geothermometry. The uniform S isotope ratios suggest that all of the S in the deposits was derived from a homogeneous source. The heavy S isotope ratios indicate that seawater acted as the source of sulfide for precipitation of metals. The presence of residual bitumen, and white sparry dolomite precipitation in conjunction with high $\delta^{34}S$ of sulfides suggest that reduced S, for precipitation of the sulfide, was supplied by in situ inorganic reduction of seawater sulfate.

Geological evidence and isotopic features are consistent with the genetic scheme that base metal mineralization was caused by dewatering of the metalliferous sediments in a rift-related basin. The heat needed to derive this system is thought to have been provided by rifting. H_2S needed for mineralization was produced by chemical reduction of seawater sulfate by hydrocarbons. Therefore evidence relating to ore genesis at Nanisivik is in accordance with a mixing model where the fluids carrying metals and hydrocarbons were guided through the faults into the Upper Society Cliffs dolostones and subsequently interacted with sulfate and possibly metal-bearing fluids. Sulfide and carbonate gangue precipitation occurred when the system became supersaturated with respect to sulfide and carbonates. (Author's abstract)

GIAMELLO, M. and RICCOBONO, F., 1988a, Genesis of the Pb-Zn deposit of S. Antonio di Val d'Aspra (GR): Contrasting evidence from field data, isotopic measurements, and preliminary fluid inclusion microthermometry: Atti Accad. Fisiocritici Siena, ser. XV, p. 33-40 (in Italian; English abstract). Authors at Ist. di Mineral., v. Mattioli 4, 53100 Siena, Italy.

Field and isotopic data coming from the S. Antonio deposit strongly support a low T origin, in a supergene environment. On the other hand microthermometry of fluid inclusions suggest the involvement of hydrothermal fluids. These sharp, contrasting, evidences are briefly discussed. (Authors' abstract)

GIAMELLO, M. and RICCOBONO, F., 1988b, Contribution to the knowledge of Mo-Sn-W deposits associated with Hercynian plutonites: The Sn mineralization at Golpejas (Salamanca). Fluid inclusion studies: Atti Accad. Fisiocritici Siena, ser. XV, p. 41-47 (in Italian; English abstract). Authors at Ist. di Mineral., v. Mattioli 4, 53100 Siena, Italy.

The Golpejas Sn-Ta ore deposit lies within an altered leucocratic microgranite in the north of the Salamanca region. Fluid inclusion study carried out on the mineralized quartz-veins, crosscutting the ore-bearing igneous body, revealed a quite complex family from the compositional view point. Many inclusions, in fact, usually contain very variable quantities of CO_2. Both the fluid inclusion composition and the evolution of the hydrothermal fluids appear greatly influenced by a peculiar pressure regime favored by the surrounding impervious metamorphic cover. (Authors' abstract)

GIBSON, P.C., 1988, Geology of the Buckskin mine, Douglas County, Nevada (abst.), in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 748. Author at Mackay Sch. Mines, Univ. Nevada-Reno.

See Gibson, 1987, in Fluid Inclusion Research, v. 20, p. 133-134. (E.R.)

GIGASHVILI, G.M., GREBENCHIKOV, A.M., NARTIKOEV, V.D. and TARKHANOV, G.V., 1988, Use of fluid inclusions in catagenic minerals, the reflectance of vitrinite, and present-day temperatures for studying the evolution of the geothermal field in petroliferous basins, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 121-127 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 136-137. (E.R.)

GIGGENBACH, W.F., 1988, Geothermal solute equilibria. Derivation of Na-K-Mg-Ca geoindicators: Geochimica Cosmo. Acta, v. 52, p. 2749-2765. Author at Chem. Div., DSIR, Petone, New Zealand.

Relative Na, K, Mg, and Ca contents of thermal waters in full equilibrium with a thermodynamically stable mineral system derived through isochemical recrystallization of an average crustal rock are, at a given T and salinity, uniquely fixed. Together with the compositions of waters resulting from isochemical rock dissolution, they provide valuable references for the assessment of the degree of attainment of fluid-rock equilibrium. (From the author's abstract)

Equations are given for K-Na, K-Mg, and K-Ca. (E.R.)

GILMER, A.L., CLARK, K.F., CONDE C., Jose, HERNANDEZ C., Ignacio, FIGUEROA S., J.I. and PORTER, E.W., 1988, Sierra de Santa Maria, Velardena mining district, Durango, Mexico: Econ. Geol., v. 83, p. 1802-1829. First author at Dept. Geol. Sci., Univ. Texas at El Paso, El Paso, TX 79968. Continued next page.

The Sierra de Santa Maria Pb-Zn-Ag ore deposits have been exploited since the sixteenth century. Major sulfide minerals existent within the dome include pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, and galena. Sulfide mineralization occurs as skarn-replacement, carbonate-replacement, disseminated, breccia, and epithermal fissure vein ore. The ore zones are divided and named on the basis of the dominant sulfide peculiar to their respective assemblages.

A variety of alteration assemblages are recognized within the dome. These are, in order of occurrence, presulfide-stage prograde skarn, potassic and propylitic alteration; sulfide-stage retrograde skarn; late sulfide-stage phyllic alteration; and postsulfide-stage argillic alteration. Prograde and retrograde skarn, potassic, propylitic, and phyllic alteration are all attributed to hypogene hydrothermal activity while argillic alteration is probably a supergene effect. Fluid inclusion analyses reveal that two distinct fluids caused prograde skarn alteration (550°C, 0.75 kb, 10 eq wt % NaCl) and sulfide mineralization (375°C, 0.12 kb, 40-60 eq wt % NaCl). A fracturing and related boiling event after skarn formation but prior to sulfide mineralization is proposed to explain the P and compositional variations between fluids.

Sulfur isotope analyses of the sulfides (0‰ vs. CDT) and host Mesozoic sedimentary rocks (-7.3 - 3‰ vs. CDT) suggest that the sulfur was derived from a juvenile (i.e., magmatic) source. No δ^{34}S compositional variations were observed paragenetically or spatially.

Finally, the variation in sulfide mineralogy between ore zones is attributed to zonation, apparently controlled by increasing sulfur and oxygen fugacities as the hydrothermal fluid migrated away from the stock. This effect was probably due to increasing small-scale meteoric ground-water interaction with magmatically derived hydrothermal fluids distally from the stock. (From the authors' abstract by E.R.)

GIORDANO, T.H., 1988, Metal-organic complexing in sedimentary basin brines (abst.): Terra cognita, v. 8, p. 173. Author at Dept. Earth Sci., New Mexico State Univ., Las Cruces, NM, USA.

Crude oil compositions, hydrous degradation studies of kerogen, and observed compositional changes of kerogen with depth in sediments all suggest that sedimentary basin brines (diagenetic fluids and ore fluids) with access to organic material should contain a variety of dissolved organic ligands. Although many of the organic species detected in recent sedimentary basin brines are capable of forming metal-orgnic complexes, only a few of them meet the requirement of an important complexing agent.

The most promising organic ligands found in recent sedimentary basin waters are acetate and succinate. Experimental studies suggest that certain simple phenolic molecules (e.g., hydroquinone and catechol) may also be important complexing agents in some basin waters. The half-life of acetate under hydrothermal conditions suggests that many potential organic ligands were in basin waters during the early stages of basin development and were there in high enough concentrations to bind a significant portion of the dissolved metals in the form of metal-organic complexes. Speciation models for metal-organic complexes in sedimentary basin brines have been developed based on high T thermodynamic data (to 300°C) for acetate complexes of Zn^{2+}, Fe^{2+}, Pb^{2+}, and Al^{3+}; low T data (near 25°C) for acetate complexes of competing metals, succinate complexes, and phenolic complexes; and available data on chloride, carbonate, sulfate, and hydroxide complexes. These models suggest that acetate complexes can account for a significant proportion of metals in basin waters which have acetate levels near 0.5 molal and pH's near neutral. Succinate and phenolic complexes may be important but under conditions more restricted than those of acetate complexing. (Author's abstract)

GIRARD, J.P., SAVIN, S.M., ARONSON, J.L. and WALGENWITZ, F., 1988a. Nature and origin of diagenetic fluids in the Lower Cretaceous arkoses of the Angola offshore basin (abst.): Chem. Geol., v. 70, p. 184. Authors at Dept. Geol. Sci., Case Western Reserve Univ., Cleveland, OH 44106, USA.

The Lower Cretaceous (115-130 Ma) arkoses of Angola offshore have been extensively diagenetically altered. The results of a multidisciplinary study, including petrology, K/Ar, $^{18}O/^{16}O$ and fluid inclusion data, provide information about the timing and conditions of formation of the diagenetic cements as well as the nature and origin of the diagenetic fluids.

Precise time relationships among the various diagenetic cements are established from petrologic observations and K/Ar dating. K-feldspar overgrowths formed first, at around 100 Ma, followed by discrete development of quartz overgrowths. Then, well developed dolomite (± calcite) cement and at last clay cement precipitated. Diagenetic clays are: 1) an IMII-ordered illite/smectite of Eocene age (50 Ma) and/or 2) a pure illite of Miocene age (16 Ma), both commonly mixed with 3) an Fe-rich chlorite.

Fluid inclusion data from the K-feldspar, quartz and dolomite cements show that diagenetic fluids were high T (110 to 160°C) brines (24 wt. % eq. NaCl). Estimated T of formation of the diagenetic clays, based on K/Ar ages and burial history diagrams, are 60-80°C for the IMII illite/smectite and 120-140°C for the illite.

The $^{18}O/^{16}O$ ratios indicate that diagenetic fluids were enriched in ^{18}O with $\delta^{18}O$ values between 1 and 5‰ for the IMII and between 5 and 10‰ for the K-feldspar, dolomite and illite cements. Such values preclude any significant, direct contribution of meteroic water. These fluids may have been derived from the Aptian evaporites overlying the sediments studied. (Authors' abstract)

GIRARD, J.P., SAVIN, S.M., ARONSON, J.L. and WALGENWITZ, Frederic, 1988b, Diagenesis of the Lower Cretaceous arkoses of Angola: Petrology, K/Ar, $^{18}O/^{16}O$ and fluid inclusions (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 345. First author at Dept. Geol. Sci., Case Western Reserve U., Cleveland, OH 44106.

The Lower Cretaceous (120-130 Ma) arkoses of Angola offshore have been extensively diagenetically altered. The results of a multidisciplinary study provide information about the succession of diagenetic cements, the paleogeothermal gradients and the nature and origin of the diagenetic fluids.

The detrital framework is composed of quartz, feldspars, micas and garnet. Precise time relationships among the various diagenetic cements are established from petrologic observations and K/Ar dating. K-feldspar overgrowths formed first, at around 100 Ma, followed by discrete development of quartz overgrowths. Then, well developed dolomite (± calcite) cement and at last clay cement precipitated. Diagenetic clays are: 1) an IMII-ordered illite/smectite of Eocene age (50 Ma) and/or 2) a pure illite of Miocene age (16 Ma), both commonly mixed with 3) an Fe-rich chlorite.

Fluid inclusion data from the K-feldspar, quartz and dolomite cements show that diagenetic fluids were high T (120 to 150°C) brines (24 wt % eq. NaCl). These data suggest the existence of high geothermal gradients during early, and maybe late Cretaceous times. The $\delta^{18}O$ values indicate that fluids from which K-feldspar, dolomite and illitic clays precipitated were enriched in ^{18}O (2 to 9‰). Such values are typical of formation waters and attest to the absence of any important meteoric contribution. They may have been derived from the Aptian evaporites overlying the sediments studied. (Authors' abstract)

GITTINS, John, 1988, Partial melting of fenitized crustal xenoliths in the Oldoinyo Lengai carbonatitic volcano, Tanzania: Discussion: Am. Mineral.,

v. 73, p. 1465-1467. Author at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

Morogan and Martin (1985) have proposed that the alkalic carbonatite lavas (natrocarbonatite) of Oldoinyo Lengai were produced by partial melting of a regionally fenitized basement to generate two conjugate immiscible liquids: the carbonatite and the associated silicate lavas. The proposed origin is not viable. The existence of a regionally fenitized basement has not been established nor is it likely, certainly not by the method proposed. Immiscibility is restricted to systems with alkali carbonates, and so even if a regionally developed fenite composed of nepheline + alkali feldspar + clinopyroxene + calcite did exist, it would not produce alkali-rich carbonatite melt and phonolite magma as conjugate liquids. The high F and Cl contents of the carbonatite lava have no obvious source in the alleged fenite basement, nor can the high concentrations of Nb, REEs, Sr, Ba, Th, Pb, or U be explained in this way. Sr- and Nd-isotope values are generally consistent with a mantle origin and offer little support for derivation from Archean basement. The alkalic carbonatite lavas of Oldoinyo Lengai cannot have been formed by partial melting of fenite. (Author's abstract)

See also Martin and Morogan, 1988, this volume. (E.R.)

GIULIANI, G., LI, Y.D. and SHENG, T.F., 1988, Fluid inclusion study of Xihuashan tungsten deposit in the southern Jiangxi province, China: Mineral. Deposita, v. 23, p. 24-33. First author at ORSTOM, Embaixada da Franca, CP 665, 70404 Brasilia DF, Brazil.

The Xihuashan tungsten deposit is closely related to a small highly evolved granitic intrusion. The fluid phases associated with the wolframite-bearing quartz veins have been investigated using microthermometry and the Raman microprobe; they are highly variable in density and composition. The earlier fluids are low-density and low-salinity CO_2-bearing aqueous solutions circulating at T up to 420°C, and low-salinity (2-3 eq. wt% NaCl) aqueous solutions without traces of CO_2 circulating at high T 280°-400°C) involved in a specific hydrothermal fracturing event; limited unmixing occurs at 380°C and 200-100 bar in response to a sudden pressure drop. The second types of fluids related to deposition of idiomorphic drusy quartz are typical CO_2-bearing aqueous solutions with low salinity (2.5 eq. wt% NaCl) homogenizing at low to moderate T (180°-340°C). The late fluids characterize the sulfide deposition stage; they are aqueous fluids with variable salinities homogenizing in the liquid phase between 100° and 275°C. The Xihuashan hydrothermal evolution resulted from a discontinuous sequence of specific events occurring between 420° and 250°C and during a continuous hydrothermal evolution of the system during cooling. The role played by the CO_2-rich fluids in the transport and deposition of tungsten in the hydrothermal environment is discussed. (Authors' abstract)

GIULIANI, G. and WEISBROD, A., 1988, Scanning electron microscopy (SEM) and its applications: Determination of solid and daughter minerals in fluid inclusions from some Brazilian emerald deposits: VII Latin-Am. Geol. Cong., Belém, PA, Brazil, Abstracts, p. 413 (in Portuguese). First author at Dep. de Geoci., Univ. Brasília, CEP 70910, Brasília, DF, Brasil.

Chemical and morphological information obtained by SEM, with previous optical observations, allowed not only to get new gemological data of Brazilian emeralds but above all the identification of dms of the fluid inclusions.

Two types of deposits has been studied: those with evident genetic relations with granitoids (e.g., Carnaiba and Socotó, Bahia), and others where relations with pegmatitic veins are dubious (e.g., Santa Terezinha and Itaberaí, Goiás). In the later the emerald is associated with zones of phlogopites where the metasomatic zoning is the result of solution percolation through fine rock porosity. Chemical reactions in the rock led to alteration in composition of the solution. As a consequence there were changes in the solid inclusions and dms trapped in the emerald. These metasomatic reactions between Be-rich fluids and basic formations rich in Cr, Mg, Fe, produced the phlogopite, amphibole (tremolite and/or actinolite) emerald and sulfides (pyrite, chalcopyrite and pentlandite) in all the deposits studied.

Differences among the deposits studied are: 1) in types of associated fluid inclusions: the emeralds from Carnaiba and Socotó generally show tubular inclusions with various shapes (needles, tubes, hexagonal channels or as "belemnite shell" shape). At Santa Terezinha and Itaberaí inclusion cavities are scarce and developed from solid inclusions; and 2) in solid inclusions and dm content: a) Cr-rich carbonated schists from Santa Terezinha permitted the formation and trapping of dolomite, ankerite, Mg-amphibole, and Mg-chromite; b) emeralds related to pegmatitic veins from Socotó and Carnaiba are rich in complex salt dms. In Socotó one can clearly see the evolution of the fluid from pegmatitic vein (I) to the adjacent phlogopite zone (II): In (I) quartz from the matrix presented dms with K, Cl identified as sylvite and other salts with Ca, Cl, Fe, all associated with multiphased fluid inclusions. Emerald grown in (I) also presented mixing of complex salts: Fe, Cl, Ca, Cl, Mn, Fe; Fe, Cl, Mn; Ca, Cl, Fe, Ba, K. In emeralds from phlogopite (II) dms contain: Ca, Cl, Fe, Mn, K; Cl, Mg, Fe; Cl, Na, Mg; and constant presence of Mg, a mobile element, supplied by serpentinites during fluid percolation. In Santa Terezinha and Itaberaí dms are almost absent indicating dilute solutions. (Authors' abstract, translated by K. Fuzikawa)

GLASER, L.M. and KEAYS, R.R., 1988, Genesis of volcanogenic epithermal gold-silver mineralization, Budawang Rift, New South Wales (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 268-270. Authors at Dept. Geol., Univ. Melbourne.

Fluid inclusions yield T of mineralization of 320°-380°C for the Au-Ag deposits, and 290°C for pyrophyllite. System fluids were highly saline, ranging from 12 to 17 wt.% NaCl eq. for the Au-Ag deposits, to 9% for the pyrophyllite deposits. Salt species are NaCl dominant with variable amounts of $CaCl_2$. No carbon dioxide was documented in fluid inclusions. Depth calculations for mineralization using the salinity corrected critical path of boiling fluids (most of the intra-rift deposits display evidence of phase separation) yield depths of 800 - >1600 m. (From the authors' abstract)

GLIKIN, A.E. and SINAI, M.Yu., 1988, The genetic role of inclusions in crystals during metasomatism, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 38-43 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 140-141. (E.R.)

GLOVER, R.B., 1988, Boron distribution between liquid and vapor in geothermal fluids: Proc. The 10th New Zealand Geothermal Workshop, Univ. Auckland Geothermal Inst., 1988, p. 223-227.

GLYNN, P.D., 1988, Modeling solid-solution reactions in aqueous systems (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Author at U.S.G.S., 432 National Center, Reston, VA 22092.

Guggenheim's two-parameter excess free-energy function, $G^E/RT = x(1 - x)[a_0 + a_1(2x - 1)]$, successfully describes solid-solution free energies as a function of composition in the $(Ba, Sr)CO_3$-H_2O, $K(Cl, Br)$-H_2O and $Na(Cl, Br)$-H_2O systems. Phase diagrams are constructed that describe stoichiometric saturation (Thorstensen and Plummer, 1977, Am. J. Sci. 277, 1203) as well as thermodynamic equilibrium states (Lippmann, 1980, N. Jb. Miner. Abh. 139, 1). The diagrams use experimentally determined a_0 and a_1 values and, alternatively, estimates of miscibility gaps, spinodal gaps, and critical-mixing T. Stoichiometric saturation is shown to control the initial congruent dissolution of relatively insoluble solids, such as strontian aragonites and strontian witherites. Thermodynamic equilibrium is attained, however, in systems with very soluble salts, such as K(Cl, Br)-H_2O or Na(Cl, Br)-H_2O. (Author's abstract)

GOELLNICHT, N.M., DIMO, Gorol, GROVES, D.I. and McNAUGHTON, N.J., 1988, An epigenetic origin for the Telfer gold deposit (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 79-84. First author at Dept. Geol., Univ. Western Australia, Nedlands 6009, Australia.

Fluid inclusions in quartz contain very complex saline fluids that homogenize between 225 and 440°C: a P estimate is 2 kb, but the uncertainty is large. The inclusions vary from moderate salinity aqueous fluids to mixed H_2O-CO_2 fluids and high salinity, multi-salt (halite, sylvite, dawsonite) inclusions: the salinity range is 21 to 54 wt.% NaCl eq. for aqueous fluids and >23 wt.% NaCl eq. for H_2O-CO_2 fluids. Salinity-T relationships between these fluids are best interpreted as due to mixing of hot, high salinity (magmatic) fluids with cooler, lower salinity (basinal or meteoric) waters: i.e., an interpretation compatible with the Pb isotope data. The highly variable CO_2 content is interpreted to be due to liberation of CO_2 from interaction with, and replacement of, carbonate-rich horizons in the succession. All new field, textural, fluid inclusion and isotopic data favor an epigenetic origin for the Telfer Au-Cu mineralization, by magmatic fluids, carrying Au and Cu as chloride complexes, along dome-related structures and along bedding planes in more fissile units in the sedimentary succession. Fluid mixing, changes in fluid chemistry induced by carbonate dissolution and/or adsorption of Au by carbonaceous material in the host rocks are the most likely Au-depostional mechanisms. (From the authors' abstract)

GOELLNICHT, N.M., GROVES, I.M., GROVES, D.I., HO, S.E. and McNAUGHTON, N.J., 1988, A comparison between mesothermal gold deposits of the Yilgarn Block and gold mineralization at Telfer and Miralga Creek, Western Australia; indirect evidence for a nonmagmatic origin for greenstone-hosted gold deposits: Univ. West. Australia, Geol. Dept. & Extension Service, v. 12, p. 309-319.

GOFF, Fraser, SHEVENELL, Lisa, and GARDNER, J.N., 1988, The hydrothermal outflow plume of Valles caldera, New Mexico, and a comparison with other outflow plumes: J. of Geophy. Res., v.93, n.B6, p.6041-6058.

GOFFE, B., MURPHY, W.M. and LAGACHE, M., 1987, Experimental transport of Si, Al and Mg in hydrothermal solutions: An application to vein mineralization during high-temperature, low-pressure metamorphism in French Alps: Contrib. Mineral. Petrol., v. 97, p. 438-450.

GOLD, Thomas, 1987, Power from the earth; Deep earth gas-energy for the future: J.M. Dent & Sons Ltd., London, 203 pp.

A summary of the author's arguments and lines of evidence that large amounts of methane are continuously outgassing from the deep interior. (E.R.)

GOLDFARB, M.S. and DELANEY, J.R., 1988, Response of two-phase fluids to fracture configurations within submarine hydrothermal systems: J. of Geoph. Res., v.93, n.B5, p.4585-4594.

GOLDFARB, R.J., HOFSTRA, A.H., LANDIS, G.P. and LEACH, D.L., 1988, H_2S-rich vein-forming fluids at the Sumdum Chief gold mine, southeastern Alaska: U.S. Geol. Survey Circular C1016, p. 160-163.

The Sumdum Chief mine was the largest Au producer within the southern part of the Juneau Au belt yielding 24,000 troy oz of Au and 24,000 troy oz (746,000 g) of Ag from a mesothermal vein system. This vein system has an unusual fluid composition that is exceptionally enriched in hydrogen sulfide. The main Au-bearing quartz vein is largely within a fissile graphitic limestone unit of a belt of phyllite and slate. All microthermometric measurements were made on fluid inclusions appearing as water-dominant, two-phase systems at room T.

Tm ice in both sphalerite and quartz ranged from -2°C to -6°C, corresponding to 4 to 9 eq. wt. % NaCl. These salinities are maximum values because the formation of observed gas clathrates removed water from the residual fluids and lowered the measured melting T. Gas-rich inclusions in sphalerite have Tm clathrate between 10.3°C and 11.4°C, and show Tm CO_2 as low as -62.5°C. Both the depression of the CO_2 triple point to below -56.6°C and the presence of clathrate meltings above 10°C indicate the presence of other volatiles in the inclusions in addition to H_2O and CO_2. The majority of the measured Th for fluid inclusions in sphalerite ranged from 215°C to 290°C.

Melting of solid CO_2 in quartz has not yet been observed, although Tm clathrate ranged from 10.7°C to 27.5°C. Values at the high end of this range are among the highest recorded for any known Au-bearing vein system and indicate an exceptionally anomalous ore fluid composition for some of the vein material at the Sumdum Chief mine. Proximity of these higher values to the 29.5°C quadruple point for the H_2O-H_2S system suggests substantial H_2S in the inclusions. Laser Raman microprobe spectroscopy confirmed the presence of H_2S in these inclusions, as well as CO_2, N_2, and CH_4. Isolated inclusions in quartz yielded Th between 240°C and 320°C.

Fluid inclusion gas analyses [(33), were] obtained using a quadrupole mass spectrometer. [Analyses were for H_2O, CO_2, N_2, CH_4, C_nH_m, HCl, Ar, H_2S, SO_2, and H_2, and showed up to 30 mol. % H_2S.] (From the authors' text by E.R.)

GOLDFARB, R.J., LEACH, D.L. and PICKTHORN, W.J., 1988, Application of fluid inclusion and stable isotope techniques to the study of Tertiary mesothermal gold deposits, southern Alaska, USA (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 439-441. First author at USGS, Box 25046, Denver Fed. Center, Denver, CO 80225.

Th for all fluid inclusions believed related to Au deposition are between 150°C and 310°C, with the majority in the 210°C to 280°C range. Most estimated fluid inclusions densities fall within a range of .75 to .90 g/cm^3, although some of the denser, more CO_2-rich fluids approach 1.0 g/cm^3. Established CO_2-H_2O-NaCl phase relationships and fluid inclusion decrepitation P for quartz suggest minimum trapping P of 1-2 kb. These P correspond to minimum depths of formation of 3.5 - 7 km for lithostatic conditions or even deeper minimum crustal levels assuming some hydrostatic component to the P.

Gas analyses were made by laser Raman spectroscopy and mass spectroscopy. Fluid inclusion compositions are characteristic of those usually produced under medium-grade metamorphic conditions, such as a greenschist and amphibolite facies reaction boundaries. (From the authors' abstract)

See also next item and Goldfarb et al., 1987, in Fluid Inclusion Research, v. 20, p. 140-141, 1987. (E.R.)

GOLDFARB, R.J., LEACH, D.L., PICKTHORN, W.J. and PATERSON, C.J., 1988, Origin of lode-gold deposits of the Juneau gold belt, southeastern Alaska: Geology (Boulder), v. 16, no. 5, p. 440-443. Continued next page.

See also previous item and Goldfarb et al., 1987, in Fluid Inclusion Research, v. 20, p. 14-141, 1987. (E.R.)

GOLDING, S.D., GROVES, D.I., McNAUGHTON, N.J., BARLEY, M.E. and ROCK, M.S., 1987, Carbon isotopic composition of carbonates from contrasting alteration styles in supracrustal rocks of the Norseman-Wiluna belt, Yilgarn Block, western Australia: Their significance to the source of Archaean auriferous fluids: Univ. Western Australia, Geol. Dept., Publ. No. 11, p. 215-238. First author at Dept. Geol. & Mineral., Univ. Queensland, St. Lucia 4015, Australia.

C-isotope data for carbonates from four alteration styles from the Norseman-Wiluna Belt provide new constraints on the sources and evolution of auriferous ore fluids.

1. The earliest-formed C reservoir in the greenstone belts comprises widespread but relatively minor calcite filling vesicles and interpillow spaces of basalts, particularly in the upper parts of the volcanic succession. Geological evidence and the $\delta^{13}C$ of the interpillow calcite (mean = -1.4 ± 0.9‰, median = -1.35‰, n = 12) are consistent with carbonation during hydrothermal (sea floor) metamorphism. This carbonate cannot be the sole, or even a major, source of CO_2 in auriferous ore fluids because it has a more positive $\delta^{13}C$ than Au-related carbonates.

2. Regional, largely pre-metamorphic, carbonation zones, related to major faults and developed mainly in komatiite sequences at lower stratigraphic levels, represent the second major C reservoir. Geological evidence and $\delta^{13}C$ of carbonate in komatiites (mean = -4.6 ± 1.0‰; median = -4.8‰, n = 28) indicate that this carbonate formed from mantle-derived fluids which were channeled up transcrustal faults. The absence of a coupled ^{13}C and ^{18}O depletion trend with increasing metamorphic grade in altered komatiites suggests that any CO_2 contribution to ore fluids was via dissolution rather than decarbonation processes.

3. Carbonates from district-scale carbonation of porphyries around the Kambalda Dome have $\delta^{13}C$ values (mean = -5.1 ± 0.6‰; median = -4.9‰; n = 27) which are statistically indistinguishable from those in carbonated komatiites, and are also consistent with a mantle fluid origin. District-scale carbonation also forms a broad halo around the more restricted individual Au deposits at Kalgoorlie. Carbonates from a number of localities within this carbonation zone have mean $\delta^{13}C$ values around -3‰. This may be due to mixing of CO_2 derived from the two premineralization C reservoirs, or may reflect reworking (e.g., continued dissolution and reprecipitation) of regional, mantle-derived carbonate alteration during regional metamorphism.

4. More-restricted Au-related alteration shows distinctive ^{13}C and ^{18}O isotopic signatures, even in different Au deposits from the same areas (Kalgoorlie and Kambalda), and a variable relationship to district-scale alteration in its vicinity. Median $\delta^{13}C$ values relate as follows: Victory (≈ -7‰) < Hunt (≈ -5‰) ≈ district-scale alteration around Kambalda Dome (≈ -5‰); Charlotte and Reward bodies, Mt. Charlotte (≈ -5‰) < No. 4 lode, Golden Mile (≈ -3‰) ≈ district-scale alteration at Kalgoorlie (≈ -3‰).

The recognition of a major mantle-derived C reservoir in regional carbonation zones affecting komatiite sequences negates recently published arguments that the C in greenstone carbonate reservoirs is too heavy to allow derivation of the isotopic compositions of Au-related carbonates by metamorphic fluids. Furthermore, the statistical differences between C-isotope ratios of individual Au deposits from the same Au camp downgrade genetic arguments based on statistical comparisons between specific Au deposits and other deposit styles. The C isotopic results for Au-related alteration strongly suggest an ultimate mantle origin for the CO_2, but the provinciality of the data is more compatible with the involvement of local-scale metamorphic hydrothermal systems in Au mineralization. (Authors' abstract)

GOLDING, S.D. and WILSON, A.F., 1987, Oxygen and hydrogen isotope relationships in Archaean gold deposits of the Eastern Goldfields Province, western Australia: Constraints on the source of Archaean gold-bearing fluids: Univ. Western Australia, Geol. Dept., Publ. No. 11, p. 203-213. Authors at Dept. Geol. & Mineral., Univ. Queensland, St. Lucia 4015, Australia.

O and H isotopic studies of vein and alteration assemblages associated with Au deposits at Norseman, Kambalda and Kalgoorlie in the Eastern Goldfields Province, Western Australia, provide constraints on the source of Archaean Au-bearing fluids. All studied deposits show, to varying degrees, a systematic $\delta^{18}O$ enrichment with wall rock alteration. Contoured O-isotope data for proximal chloritic and bleached dolerites from the Mount Charlotte deposit, Kalgoorlie, define central zones of high $\delta^{18}O$ values which are coincident with economic stockwork-style Au mineralization, and indicate the strike- and oblique-slip faults were channel-ways for ore fluids. Zones of anomalously high $\delta^{18}O$ surrounding the other Au deposits are less well-defined because of the more complex structural styles.

The narrow range of $\delta^{18}O$ values for vein quartzes of +10 to +13 ‰ from all deposits, and over vertical extents of hundreds of meters at Mararoa-Crown, Norseman, and Mount Charlotte, Kalgoorlie, indicate homogeneous ore fluids and a stable P-T regime during mineralization. O and H isotopic data, together with fluid inclusion studies, suggest that modified sea water ($\delta^{18}O$ = +7.4 ± 0.4‰, δD = -10 ± 4‰ at 400° ± 10°C) is the most probable fluid source for the premetamorphic peak deposits at Norseman. Calculated ore-fluid compositions for the syn- to post-metamorphic peak deposits at Kambalda (Victory mine, $\delta^{18}O$ = +7 ± 2‰, δD = -30 ± 12‰ at 350° ± 50°C) and Kalgoorlie (No. 4 lode: $\delta^{18}O$ = +6.5 ± 2% at 300° ± 50°C; Mount Charlotte: $\delta^{18}O$ = +7 ± 2‰ at 350° ± 50°C), geologic considerations and previous fluid inclusion studies suggest that these deposits mainly reflect metamorphic fluid activity. The isotope and other data cannot discount a mantle-derived and/or magmatic component in the ore fluids.

Preliminary isotopic studies of subeconomic and barren veins, together with the substantial isotope database for economic vein systems, indicate that the analysis of silicate $\delta^{18}O$ whole-rock and vein-quartz values may be a valuable technique at the developmental stage of exploration for Archaean Au deposits. (Authors' abstract)

GOLDSTEIN, R.H., 1988, Cement stratigraphy of Pennsylvanian Holder Formation, Sacramento Mountains, New Mexico: AAPG Bull., v. 72, no. 4, p. 425-438. Author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706.

Cyclic strata of the Holder Formation (Virgilian, New Mexico) were deposited across a Pennsylvanian shelf-to-basin transition during a time when sea level fluctuated over tens of meters. Cement-stratigraphy studies indicate abundant calcite precipitation from low-T fresh water within shelf, shelf-crest, and shelf-edge marine limestones. Fresh water cementation occurred during 15 periods of intraformational subaerial exposure. These early cements are least abundant in basin and lagoon limestones. The distribution of the early cement zones suggests that cementation was controlled by paleotopography, stratigraphic position below subaerial exposure surfaces, lithology, and configuration of the paleoaquifer system. Distribution of early calcite cements provides new data for interpretation of cycles, diagenetic systems, and porosity evolution in petroleum reservoirs. Trace-element analyses support a low-T, fresh water origin for the early cements. Cement-stratigraphy studies, fluid inclusion analyses, and trace-element analyses indicate a later cement that occluded remaining limestone porosity precipitated from a sodium- and calcium-rich brine at a T of about 100°C. Stratigraphic reconstruction dates this cementation as Cretaceous or later. Fluorescent, oil-filled fluid inclusions were trapped along fractures in the late cement, indicating oil migration during or after ate-state cementation. (Author's abstract)

GOLEVA, G.A. and KULIKOV, I.V., 1988, On the problem of skarn ore formation in the Caucasus: Izvest. Visshikh Uchebnykh Zavedenii, Geol. i Razvedka, 1988, no. 7, p. 58-65 (in Russian; abstract courtesy I.V. Kulikov). Full translation in Int'l. Geol. Review, v. 30, no. 6, p. 676-683).

Comparison of the compositions of brine inclusions from Tyrnyauz with deep brines from the Caucasus depressions show them to be very similar: 1) Ca >> Na and K, (as chlorides); 2) CH_4 and N_2 > CO_2; 3) both contain Cu, Zn, Pb; and 4) both have pH <7. There is a possibility that these two fluids have the same origin, and that such fluids have extracted and transported the W and Mo for Tyrnyauz. (E.R.)

GONCHARENKO, O.P. and MOSKOVSKY, G.A., 1988, Conditions of formation of salts in the concluding phases of halogenesis based on inclusions in minerals (western part of the Caspian Basin), in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 131-137 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 144-145. (E.R.)

GONZALEZ-PARTIDA, Eduardo, 1988, Fluid inclusions in geothermics; a new tool of experimental petrology applied to well AZ-44 Los Azufres, Michoacan, Mexico: Geotermia, Rev. Mex. Geoenergia, v. 4, p. 3-13 (in Spanish; English abstract). Author at Inst. de Investiga. Eléctricas, Interior Internado Palmira, Apartado Postal 475, 62000 Cuernavaca, Mor., Mexico.

The new formation minerals in hydrothermal systems show a thermal evolution with their precipitation in time and space. Such thermal record can be measured with a technique called microthermometry-microscopy of fluid inclusions. This method allows simultaneous determination of the physical-chemical characteristics of the initial brine that took part in the water-rock interaction, and also to study its boiling processes and estimations of the initial P of the system. Therefore well AZ-44 was studied using different new formation minerals: quartz, epidote, calcite, wairakite. T of 320°C at the bottom of the well and an homogeneous brine comparable to the actual fluid were observed. The boiling point was determined at 1660 m at 265 ± 5°C, 95 ± 5 bar and with a 10 times more concentrated brine. The phenomenon was observed in heterogeneous bubbles with either vapor or vapor-liquid phases.[sic]. (Author's abstract)

GORNITZ, V., WENRICH, K.J., SUTPHIN, H.B., and VIDALE-BUDEN, R., 1988, Origin of the Orphan mine breccia pipe uranium deposit, Grand Canyon, Arizona: In: Process mineralogy VII-As applied to separation technology, A.H. Vassiliou, D.M. Hausen, and D.J. Carson, eds., p.281-301. First author at Columbia Univ. and NASA GSFC Inst. for Space Studies, New York, NY 10025.

The Orphan mine uranium deposit, Grand Canyon, Arizona, is a cylindrical collapse-breccia pipe, 70 to 150 m in diameter and 500 m deep. Mineral assemblages at the Orphan suggest possible mixing of the metal-bearing solution(s) with a more oxidized fluid, containing soluble uranyl complexes. Th of fluid inclusions in calcite (60-110°C) at the Orphan fall within the lower end of the range observed at other breccia pipes. (From the authors' abstract)

GOTTIKH, R.P., PISOTSKY, B.I. and SVOREN', I.M., 1988, Some aspects of the metallogeny of the bitumens of the Siberian Platform, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 112-120 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 145-146. (E.R.)

GOZHIK, N.F., DEICHAKOVSKAYA, K.A., KOVALISHIN, Z.I., PEN'KOVSKAYA, B.V., PLATONOVA, E.L., UDUD, R.V. and SHKLYANKA, V.M., 1988, Evolution of composition of the mineral-forming fluids of the Beregovo deposit, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 197-202 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 147-148. (E.R.)

GRAF, J.L., 1988, Partitioning behavior of rare earth elements between calcite and aqueous solutions at temperatures and salinities similar to those for ore fluids in Mississippi Valley-type deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A95-A96. Author at Dept. Geol., Kansas State Univ., Thompson Hall, Manhattan, KS 66506.

Partitioning experiments were carried out utilizing recrystallization of natural and synthetic aragonite to calcite in the presence of dissolved La, Sm, and Lu at T up to 150°C and salinities up to 4 M. In addition, parallel experiments using calcite starting material were carried out to compare incorporation largely by adsorption with that during recrystallization.

The REE partitioned strongly into calcite in both sets of experiments, with apparent distribution coefficients (ppm solid/ppm solution) ranging from 200 to 600. Distributions of REE (i.e., REE patterns) in product calcites closely reflected the pattern in the starting solution. Variations in T and salinity had little effect on the values of apparent distribution coefficients. Apparent distribution coefficients for the calcite exchange experiments were essentially identical to those for the aragonite recrystallization experiments.

Because the apparent distribution coefficients determined in both sets of experiments were very similar, REE must be incorporated into calcite largely by adsorption rather than by substitution for Ca ions. The experimental results suggest that REE distributions in calcites can serve as indicators of the distributions in the fluids from which the calcites formed or with which they interacted. However, because the REE appear to be incorporated by adsorption rather than substitution, it will probably not be possible to calculate absolute concentrations of REE in the fluid using distribution coefficients. Likewise, it appears that salinity and T may also be difficult or impossible to infer using REE distributions in calcite. (Author's abstract)

GRAHAM, Don, 1988, Hydrothermal alteration of serpentinite associated with the Devils Mountain fault zone, Skagit County, Washington: MS thesis, Western Washington Univ., Bellingham, WA, USA.

Indexed under "Fluid Inclusions." (E.R.)

GRANOVSKAYA, N.V., 1988, The genetic and research-assessment information nature of gas-liquid inclusions in barites from the deposits of the Northwestern Caucasus, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-

Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 211-216 (in Russian).

GRANT, G.J. and RUIZ, Joaquin, 1988, The Pb-Zn-Cu-Ag deposits of the Granadena mine, San Francisco del Oro-Santa Barbara district, Chihuahua, Mexico: Econ. Geol., v. 83, p. 1683-1702. First author at Rt. 2, Box 2558, Benton City, WA 99320.

Mid-Tertiary polymetallic quartz sulfide vein deposits of the San Francisco del Oro-Santa Barbara district are among the largest Pb-Zn-Cu-Ag deposits in Mexico.

Vein formation occurred in at least four distinct stages that define an unusual paragenetic sequence when compared to similar systems. Early massive sulfide veins are cut by veins rich in calc-silicates, quartz, and late sulfides. This group is cut by two stages of postore quartz-fluorite-calcite veins with minor sulfides. Early sulfides and late calc-silicates represent a paragenetic sequence which is the reverse of that normally observed in systems containing calc-silicates and sulfides.

Stage 1 veins are characterized by abundant sphalerite and galena, and minor quartz, with weak alteration halos of epidote, axinite, chlorite, quartz, and minor andradite. Stage 1 vein quartz was precipitated from 250° to 320°C solutions with salinities ranging from 2 to 14 eq wt % NaCl. Vein-related replacement bodies were also formed during this stage of hydrothermal activity. Stage 2 veins are characterized by an abundance of calc-silicate minerals within the veins, sulfides (dominantly chalcopyrite-pyrite assemblages), a small amount of Au mineralization, and a pervasive, calc-silicate-rich alteration assemblage containing manganoan hedenbergite, manganoan ilvaite, quartz, minor andradite, and hematite. Th of fluid inclusions in late stage 2 quartz range from 180° to 300°C and salinities range from 1 to 14 eq wt % NaCl. Stage 3 and 4 veins are characterized by quartz, calcite, and fluorite. These veins were formed by 220° to 260°C fluids with salinities ranging from 1 to 3 eq wt % NaCl.

Fluid inclusion studies reveal a highly complex ore-forming history. Ore-bearing fluids varied widely in T (from 180°-320°C) and chloride concentration (from <1-14 eq wt % NaCl). Fluid inclusion petrographic evidence for boiling, however, is not prominent.

The variable T and salinity found in fluid inclusions, the distinct mineralogic differences observed between vein stages 1 and 2, and the variable age relations between veining and igneous activity suggest that the deposits of the San Francisco del Oro/Santa Barbara district were probably emplaced during several episodes and that these ores may represent the superposition of at least two distinct hydrothermal systems. (From the authors' abstract by E.R.)

GRAZIANI, Giorgio, LUCCHESI, Sergio, SCANDALE, Eugenio and STASI, Francesca, 1988, Growth defects and genetic medium of a quartz druse from Traversella, Italy: Neues Jahrbuch Miner. Abh., v. 159, p. 165-179.

Two quartz crystals from an Italian druse (Traversella, Piedmont) were studied by X-ray diffraction topography, optical microscopy and electron microprobe analysis. Growth defects, fluid inclusions, optical anomalies of the crystals and mineralogical association of the druse have been studied in relation to geological data. Range of T (150-390°C) and P limit (up to 2 Kbar) of genetic medium were determined. Optic Axial Plane orientations were observed to be related to growth defects, proving nearly perpendicular to growth horizons in the less strained crystal sectors. Micro-inclusions and impurity absorption were observed to be related to growth rates of the crystal faces. S and PS fluid inclusions were carefully differentiated by growth-history reconstruction. These observations, taken as a whole, confirm that defects of a druse present distinctive characteristics. (Authors' abstract)

GREEN, H.W. and TINGLE, T.N., 1988, Formation of fluid inclusions and tubes in olivine at high pressure (abst.): EOS, v.69, p.477. First author at Dept. of Geology, Univ. of Ca., Davis, CA 95616.

Fluid-filled tubes, 3-10 μm OD up to 1 mm long, and inclusions 5-35 μm OD, were produced in single crystals of San Carlos olivine annealed at 2-3 GPa. 1200-1400 C with CO_2-H_2O fluids sealed in Pt capsules. Observations suggest a three-stage process for their formation: (1) An incubation period of several minutes is required before (2) growth of tubes, by dissolution of olivine, proceeds more or less along one or more of the principal crystallographic directions in the host crystal. (3) Healing of tubes to form inclusions occurs after several hours and continues up to several days. ^{14}C autoradiography demonstrates the bubbles contain C and, by analogy with Roedder's (1965) observations, the bubbles contain CO_2 liquid, CO_2 vapor and H_2O. Films and blobs lining the bubble walls may represent silicate or carbonaceous material. In some specimens, one part of the crystal shows abundant inclusions, whereas other parts of the same crystal show virtually none. In almost all cases, tubes originated at the bottom of the specimen and grew upward. Less commonly, tubes grew inward from the circumference (sides) of the specimen. Oxidation of one specimen, where linear arrays of bubbles could be traced to tubes in the process of necking down, showed dislocations connecting the bubbles in the arrays. These dislocations do not lie in subgrain boundaries and are curvilinear, in some cases and might represent screw dislocations created during crystal growth. Tubes or inclusions were not produced on subgrain boundaries. Formation of tubes (etch tunnels, catalytic channels, etc.) in materials is not well understood. Etch tunnels are proposed to form by segregation of a catalyst at dislocations intersecting the crystal surface. In our experiments, the catalyst might be H diffused into the capsule from the NaCl-BN sample assemblies, which are noted for their high $f(H_2)$ and low $f(O_2)$. Experiments in NaCl-Pyrex-alumina assemblies, which appear to have a low $f(H_2)$ and higher $f(O_2)$ (greater than graphite CO_2), did not produce any tubes or inclusions under identical conditions. (Authors' abstract)

GREENWOOD, H.J., 1987, Fluid exchange between reacting bodies of rock, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 153-168. Author at Dept. Geol. Sci., 6339 Stores Road, The Univ. British Columbia, Vancouver, B.C. V6T 2B4, Canada.

Adjacent units of rock having contrasting chemistries generate fluid reaction products that have different compositions, and which are generated at different stages of pro-grade metamorphism. At constant P, a rock that generates a larger volume of fluid than its neighbor will tend to export fluid to its neighbor, particularly[sic] if the boundary between the two is not absolutely impermeable. The invasion of one rock by the fluid from another can induce reactions in the invaded rock that produce a new fluid tending to repulse the invader. At different stages, the recipient can become the donor, and vice versa, with the battle lines oscillating until one rock or the other exhausts its buffer capacity. (Author's abstract)

GREGG, J.M. and SHELTON, K.L., 1988 Stable isotopes in the back reef facies of the Bonneterre and Davis Formations (Cambrian), MO -- Evidence for a complex diagenetic history (abst.): Geol. Soc. Am. Abstract Programs, v. 20, p. A120. First author at Dept. Geol. & Geophys., Univ. Missouri, Rolla, MO 65401.

Stable C and O isotope values for limestone and dolomite in the back reef facies of the Bonneterre and Davis Formations indicate lithification of lagoonal mudstones by dilute meteoric water and dolomitization of planar stromatolites by sea water at slightly elevated salinities. (...) Complicating interpretation of early diagenesis is evidence of late alteration of these rocks during Mississippi Valley-type mineralization. (...) This interpretation is corroborated by petrographic and fluid inclusion data. (From the authors' abstract by E.R.)

GRICHUK, D.V., 1988, Isotope-chemical thermodynamic model of a hydrothermal system: Dokl. Akad. Nauk SSSR, v. 298, no. 5, p. 1222-1225 (in Russian). Author at State Univ., Moscow, USSR.

The paper presents the behavior of the sulfur isotopes in a convecting mid-ocean ridge hydrothermal system at T 350-150°C (with tholeiitic basalt as the wall rock). (A.K.)

GRIFFIN, W.L., JAQUES, A.L., SIE, S.H., RYAN, C.G., COUSENS, D.R. and SUTER, G.F., 1988, Conditions of diamond growth: A proton microprobe study of inclusions in West Australian diamonds: Contrib. Mineral. Petrol., v. 99, p. 143-158.

Crystalline inclusions were analyzed for major and many minor elements; both eclogite-suite and peridotite-suite inclusions were found. (E.R.)

GRINFEL'D, M.A., 1988, The equilibrium orientations of the rigid inclusions in non-hydrostatic fields of elastic tension: Dokl. Akad. Nauk SSSR, v. 298, no. 2, p. 333-338 (in Russian). Author at Inst. of Earth's Physics of Acad. Sci. USSR, Moscow, USSR.

The mathematical presentation of the stability conditions, deformations in matrix and equilibrium position of the rigid ellipsoid in a recrystallizing isotropic elastic matrix. May be useful in genetic studies of the solid inclusions and in solution of problems connected with decrepitation techniques. (A.K.)

GRISHINA, S.N., DUBESSY, J., KONTOROVICH, A.E. and KUDRINA, T.R., 1987, Inclusions in Cambrian salts of Bakhtinsky megaprojection as indicator of conditions of oil and gas pool formation and conservation: Geology & Geophysics (Novosibirsk), no. 12, p. 31-38 (in Russian; see Translations).

GROVES, D.I., GOLDING, S.D., ROCK, N.M.S., BARLEY, M.E. and McNAUGHTON, N.J., 1988, Archaean carbon reservoirs and their relevance to the fluid source for gold deposits: Nature, v. 331, p. 254-257. First author at Dept. Geol., Univ. Western Australia, Nedlands 6009, Australia.

It is commonly assumed that seawater-derived C in altered volcanic rocks is the only major premetamorphic C-in-carbonate reservoir in Archaean greenstone belts. Thus carbonates from Archaean Au deposits with stable isotope ratios too negative (median $\delta^{13}C \approx -3‰$) to have been derived from such C ($\delta^{13}C$ usually assumed to be near 0‰) have been interpreted as being derived from a local felsic magmatic source. Barley and Groves, however, recognize two carbonate-alteration styles that predate regional metamorphism and Au mineralization in the Norseman-Wiluna greenstone belt of Western Australia: evidence is summarized below. These are sea floor alteration and fault-controlled regional alteration, which, as shown below, have completely different C isotope compositions. The latter (median $\delta^{13}C = -4.8‰$) implies a major juvenile C (CO_2) flux from the mantle during greenstone-belt evolution, and is thus of fundamental importance in itself. However here we show why the mere existence of two C-in-carbonate reservoirs and variation in C isotope ratios of carbonates between individual Au deposits in one area, negate some of the fundamental assumptions used to support magmatic-fluid models. (Authors' abstract)

GU, Lianxin and RUAN, Huichu, 1988, On the hydrothermal origin of the Gushan iron ore deposit in Anhui Province: Mineral Deposits (Beijing), v. 7, no. 2, p. 21-30. Authors at Dept. Geol., Nanjing Univ., Nanjing, China.

The Gushan iron deposit, located at the south end of the Nanjing-Wuhu Mesozoic terrestrial volcanic-sedimentary basin, is one of the most important iron ore sources in East China. A subvolcanic augite diorite stock here intruded into the Triassic siltstones, sandstones and shales which, along with the Jurassic sandstones, formed the basement underlying the andesitic volcanics. The intensely brecciated sedimentary rocks along the contact zone provided the main structure for ore deposition. The major components of the ores are hematite (martite), quartz, chalcedony and carbonates. Hydrothermal alterations are extensively developed in this deposit and can be divided upwards for the lowest unaltered augite diorite into four zones: (1) albitized augite diorite, (2) carbonatized augite diorite, (3) siliceous or carbonate-bearing iron ores and (4) carbonatized sedimentary rocks. The widespread carbonate minerals within, below and above the ore bodies, and a considerable amount of reductive gases such as CH_4, CO and H_2 contained in the inclusions of the ore minerals indicate that carbonyl complexes may have been the important form for the remobilization of iron in augite diorite during the post-magmatic processes. (From the authors' abstract by H.E.B.)

GU, Qiaogen, RUI, Xinjian, FENG, Yichang, ZHANG, Chunsun and ZHU, Shaohua, 1988, Volcanogene ore deposits in Zhejiang, Fujian, and Jiangxi and their genetic characteristics. Bull. Nanjing Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., v. 9, no. 1, p. 21-42 (in Chinese; English abstract). Authors at IGMR, Nanjing, PRC.

In the given region Pb, Zn, Ag, Cu and Mo are the main volcanogenic ore deposits and Au and REE are prospective. They are classified as 5 types; volcano-hydrothermal, porphyry, volcano-sedimentary-hydrothermal superimposed, volcano-hydrothermal reformed and volcanite-weathered. Ore bodies occur mainly as veins and lenses, and as beds and pipes. Ore formations are chiefly pyrite-galena-sphalerite association in vein deposits (locally arsenopyrite, Ag and Au-bearing minerals), less pyrite-molybdenite-scheelite association in porphyry deposits (locally cassiterite or beryl) and magnetite-sphalerite-pyrite-galena association in skarn deposits. Country rocks suffered intermediate T alteration-beresitization and propylitization. Major metals often show vertical and horizontal zoning. According to the homogenization or decrepitation method, volcanogene ore deposits are formed ~200-300°C, with rare higher T. The P of mineralization calculated by different methods are 52-900 bar, corresponding to 200-3500 m in depth, optimal depths might be 500-2600 m. H and O isotopes in liquid inclusions and vein quartz show 4 types of hydrothermal water forming the deposits: magmatic, meteoric, metamorphic and mixed. Mixed water is widespread and the others appeared only in certain mineralization stages in individual deposits. [Sr, Pb, and S isotopes were also studied.] (From the authors' abstract by E.R.)

GUILHAUMOU, N., JOUAFFRE, D., VELDE, B. and BENY, C., 1988, Raman microprobe analysis on gaseous inclusions for the diagenetically altered Terres Noires (SE France): Bull. Minéral., v. 111, p. 577-585

Raman microprobe determinations have been made in P gaseous inclusions in quartz crystals found in concretions from diagenetically altered Jurassic sediments for SE France. The gas compositions vary as a general function of the diagenetic grade of the enclosing sediments. Two major types of gas inclusions were found, a wet gas in the western part of the basin and a dry gas in the eastern part. The proportions of CH_4, C_2H_6, C_3H_8, CO_2, H_2S and N_2 were determined to within 1% of the amount present. The gas mixtures and fluid phase assemblages indicate that these materials were entrapped during the evolution of the organic and mineral rock assemblages induced by increases of T and P. There is no evidence for change of the organic material after its entrapment as a fluid inclusion.

UV fluorescence observations indicate that organic liquids are present in the P inclusions and also in S inclusions situated in healed cracks. These S inclusions are found in the whole area. UV fluorescence measurements indicate that this trapped material could be an extract from a more evolved organic material than that found in P inclusions. These S inclusions could have been formed during a tectonic event of the Alpine orogenies. (Authors' abstract)

GUILHAUMOU, N., SONDO, D., BENY, J.M. and TOURAY, J.C., 1988, Characterization of gold-bearing quartzes from the Bouroum district (Burkina Faso). Analysis of fluid inclusions by Raman microprobe, in Metal ore deposits in their geological context, eds., Z. Johan and D. Ohnenstetter: Document du BRGM no. 158, vol. II, p. 715-728 (in French; English abstract).

The Au deposit of Bouroum (Burkina Faso) belongs to the Birrimien of the central Eburneen area of West Africa. It occurs as lower Proterozoic Au vein system in volcanic and sedimentary volcanic rocks, in a greenschist facies. The veins cut all rock types with various orientations corresponding to the main fracturing episodes. They are quartz veins with free Au, pyrite and goethite. The associations quartz-pyrite and quartz-tourmaline were successively observed. Au is very pure (97% Au), and associations with As are very rare. Four generations of quartz occur in relation to the deformation trends. Au particles are found frequently in microcracks or at the edges of some grains, in the second or third generation of quartz.

The associated fluids were trapped in very tiny inclusions, showing heterogeneous trapping. Microthermometric measurements, and Raman microprobe analysis were performed. An aqueous sodium chloride solution (low salinity), and a gaseous mixture of CO_2-CH_4 in variable amounts has been determined.

As CH_4 is mainly partitioned to the gaseous phase (sometimes 100%), and CO_2 in the aqueous phase, the mechanism of boiling of an initially homogeneous fluid seems to be consistent. This would have occurred during a T and P decrease as indicated by later aqueous inclusions of lower T. Deposition of Au could have occurred simultaneously by the rapid variation of physicochemical parameters in the solution, especially the modification of the CO_2/CH_4 ratio. T and P values were ~250°C, and 0.5 to 2 kb. (Authors' abstract)

GUILHAUMOU, Nicole, TOURAY, J.-C. and BOUHLEL, Salah, 1988, Stretching of hydrocarbon fluid inclusions in fluorite at 200 and 400 bars confining pressure. Application to low-pressure geobarometry: Bull. Minéral., v. 111, p. 421-426. First author at Lab. Géol. l'Ecole Normale Supérieure, ER 224 du C.N.R.S., 46 R rue d'Ulm, 75230 Paris Cedex 05, France.

Intrakarstic fluorite samples from Djebel Guebli (Tunisia) contain spherical primary yellow oil inclusions with detectable amounts of H_2O, CH_4 and CO_2. After overheating above Th at one bar P, decrepitation of inclusions is observed which is related to abrupt gas loss with simultaneous injection of oil droplets into microcracks. This process is not operative under elevated confining P (200 and 400 bars), but stretching occurs instead. From a comparison between T of onset of stretching for oil and water inclusions of similar volumes, an oil isochore slope of about 0.3 °C/bar is proposed for geobarometric application under low-P conditions. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p. 148. (H.E.B.)

GUILLOT, C., MOINE, B., BENY, Cl., TOLLON, F. and TOURAY, J.C., 1988, Repartition and origin of N_2 in the fluid inclusions of the dôme de Montredon, Montagne Noire, France (abst.): Chem. Geol., v. 70, p. 163. Authors at Lab. Min., UA 67 CNRS Univ. Toulouse, France.

The dôme de Montredon is an Hercynian structure involving a Lower Cambrian series (K_1 to K_{2-3}). A deep-seated granitic stock induced metamorphism in the upper epizone and fluid flow from which a tungsten mineralization was issued. The study of fluid inclusions (microthermometry, Raman microprobe), yet incomplete, has been performed mainly on synmetamorphic quartz lenses. These inclusions, more particularly the earliest ones, often exhibit a large volume of gas beside aqueous solution.

At the top of the carbon-rich black-schists formation K_2b, the stratiform scheelite-mineralization at l'Hom Haut occurs within pyroxene- and biotite-bearing schists. The gas in the earliest fluids are N_2 (40 mole %), CH_4 (> 50 mole %) and CO_2 (< 10 mole %). N_2 is still present, however in smaller amounts, within the overlying schistose formation. In other parts of the biotite-bearing black-schists formation within the dome area, N_2 is general (10-35 mole %) but CO_2 predominates over CH_4. On the contrary, N_2 is absent or scarce (microthermometry only) within the muscovite-chlorite black-schists away from the dome. On the other hand, no N_2 has been detected (CO_2 = 95 mole %, CH_4 = 5 mole % by Raman) within the micaschists formation K_1 at the base of the series.

These results suggest that the primary source of N_2 was probably the organic matter in the precursors of the black-schists. The abundance of this gas in fluid inclusions seems to be related to the metamorphic grade (break-down or recrystallization of NH_4-bearing micas). (Authors' abstract)

GULIY, V.N., 1988, Solid inclusion in minerals of the Precambrian apatite-bearing rocks of Aldan Shield: Mineral. i Geokhimiya (Leningrad), v. 7, p. 151-157 (in Russian).

Indexed under "Fluid Inclusions." (E.R.)

GUY, Bernard, FAURE, Nicole, LE LOC'H, Gaelle and VARENNE, J.-L., 1988, Microthermometric study of fluid inclusions in the tungsten skarns of Costabonne (Pyrénées, France): A few results: C.R. Acad. Sci. Paris, v. 307, p. 33-38 (in French; English summary).

Fluid inclusions contained in several minerals in the skarns of Costabonne have been studied by microthermometry. The Th range from 150 to 500°C and suggest that the skarns formed at a T interval starting at about 680°C (early stages) down to 200°C (late stage), at an estimated P of about 1.7 kb. The salinity of fluids was variable (from 5 to 25% eq. NaCl or more) and increased as T decreased. CO_2 was not detected. (Authors' abstract)

GUY, B., SHEPPARD, S.M.F., FOUILLAC, A.M., LeGUYADER, R., TOULHOAT, P. and FONTEILLES, M., 1988, Geochemical and isotope (H, C, O, S) studies of barren and tungsten-bearing skarns of the French Pyrenees, in Mineral deposits within the European community, J. Boissonnas and P. Omenetto, eds.: Publ. Springer-Verlag, Berlin, p. 53-75. First author at Dept. Géol. UA CNRS No. 384 "Métallog. & Pétrol.," Ecole des Mines, 158 Cours Fauriel, 42023 Saint-Etienne Cedex 2, France.

Both scheelite-bearing and barren skarns occur in Lower Palaeozoic carbonate formations in contact zones of Hercynian granites in the Pyrenees. Chemical analyses of the mineralized Costabonne skarns which developed in marbles show that W, U, Fe, Mn, Zn, S and less clearly Ta and Nb were introduced and elements such as Ti, Al, Zr, Hf and the REE were typically immobile.

D/H and $^{18}O/^{16}O$ analyses of minerals and fluid inclusions from the early Stage I (garnet, pyroxene, ± scheelite) indicate the dominance of metamorphic waters in barren skarns and either metamorphic or magmatic waters in mineralized skarns. Comparable minerals are typically 1‰ or more enriched in ^{18}O in barren skarns relative to mineralized ones. Fluids responsible for Stage II hydrosilicate-sulphide alteration (amphibole, chlorite, calcite, quartz, sulphides ± scheelite) were dominantly of meteoric origin whose δD value may have evolved during skarn development. ^{13}C/^{12}C and ^{18}O/^{16}O systematics of calcite are interpreted in terms of a hydrothermal decarbonation model, although a magmatic carbon contribution cannot be excluded for some calcites. ^{34}S/^{32}S analyses of minerals, with $\delta^{34}S(\Sigma S) \sim +2 \pm 1‰$ for the mineralizing fluids, do not discriminate between a magmatic or country rock source for the sulphur. In mineralized skarns, tungsten concentrations increase with increase in the importance of Stage II development.

The difference in O-isotope composition of comparable minerals from mineralized and barren skarns is a potential prospecting tool. More data are required to test this possibility and its applicability to non-Pyrenean skarns. (Authors' abstract)

GYANI, K.C. and NARAYAN, Laxmi, 1986, Petrochemistry of Archaean metasediments from gneiss-granulite terrain of Amet-Nasirabad region, central Rajasthan: Seminar on evolution of the Prec. crust in the Aravali Mt. belt, Abst. of papers, p. 18-19. Authors at Univ. Rajasthan.

Fluid inclusions from granulitic and granofelsic rocks of Bandanwara region show abundance of synmetamorphic CO$_2$ inclusions, indicating dominating role of CO$_2$ in the fluid history of these rocks. The migration of CO$_2$-rich, H$_2$O-poor fluids through the lower crust, give evidences for granulite facies metamorphism in the region. (From the authors' abstract by H.E.B.)

HACURA, Andrzej, YOON, J.-H. and BAGLIN, F.G., 1988, Density values of carbon dioxide and nitrogen mixtures from 500 to 2500 bar at 323 and 348 K: J. Chem. Eng. Data, v. 33, p. 152-154. First author at Inst. Fizyki, Uniw. Slaski, Uniw. 4, 40-007 Katowice, Poland.

The density of binary mixtures of carbon dioxide-nitrogen with mole fractions of 0.25, 0.5, and 0.74 were measured at 323 and 345 K and in a P range betwen 500 and 2500 bar. These results have been used for numerical calculations of the second and third virial coefficients of these mixtures. (Authors' abstract)

HAEFNER, R.J., MANCUSO, J.J., FRIZADO, J.P., SHELTON, K.L. and GREGG, J.M., 1988, Crystallization temperatures and stable isotope compositions of Mississippi Valley-type carbonates and sulfides of the Trenton Limestone, Wyandot County, Ohio: Econ. Geol., v. 83, p. 1061-1069. First author at U.S. Geol. Survey, 5 Aerial Way, Syosset, NY 11791.

Fluid inclusion and isotopic data indicate that dolomite, sphalerite, and calcite in the Wyandot fracture zone were deposited by warm, moderately saline, Mg- and Fe-bearing fluids. The fluids probably did not evolve from normal burial and compaction in northwest Ohio but represent gravity-driven flow of brines from an adjacent mature sedimentary basin. The Appalachian and Michigan basins are possible sources of the fluids. The large range of Th can be explained by fluid mixing, fluctuations in fluid flow rate, or T changes in the source region. A systematic decrease in fluid inclusion Th and salinities would occur in a mixing model. However, such a relationship was not observed, so a mixing hypothesis must remain speculative at this time. (From the authors' text by E.R.)

HAGGERTY, S.E., 1988, Redox heterogeneities in the upper mantle (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A31. Author at Dept. Geol., Univ. Mass., Amherst, MA 01003.

Reduction-oxidation equilibria in the upper mantle are controlled by concentration and speciation of volatiles and iron, both essential to an understanding of melt generation and petrogenetic evolutionary paths. Fluids and gases in the system COHNS are affected by liquid immiscibility (specifically in carbonate and sulfide associations), degassing, wall rock interaction, and degree of partial melting. Redox estimates for the entire upper mantle range from mildly oxidizing (FMQ) to highly reduced (<IW). This disparity derives in part from techniques applied, samples considered representative of the upper mantle, upper mantle-derived melts, and from volcanic gas emanations. Current debates are whether basalts and volcanic gases reflect parental source regions. One view holds that reduced melts are derived from oxidized upper mantle, whereas the reverse holds for oxidized melts. Another view is that preferential degassing of H and SO_2 yields melts that are oxidizing and reduced, respectively. A persistent observation is that basalts, on average, cluster in a narrow envelope around FMQ. Upper mantle-derived melts may reflect the fO_2 of melting and not the fO_2 of the source. On the other hand, upper mantle-derived xenoliths yield a consistent relationship among fO_2 and depleted lithosphere (IW-WM), fertile asthenosphere (WM-FMQ), and metasomes (>NNO). Vertical and lateral variations in upper mantle redox states have evolved with time, recycling and tectonic setting; hence, a single fO_2 condition should not be expected and cannot be uniformly applied. (Author's abstract)

HALL, D.L., BODNAR, R.J. and CRAIG, J.R., 1988, Fluid evolution during metamorphism and uplift of the massive sulfide deposits at Ducktown, Tennessee (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A46. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Standard petrographic, microthermometric and Raman spectroscopic analyses of FI from the metamorphosed massive sulfide deposits at Ducktown, TN, indicate that fluids with a wide range of compositions in the C-O-H-N-S-salt system were involved in the syn- to post-metamorphic history of these deposits. Results have been compared to theoretical calculations of fluid speciation in the C-O-H-S system at elevated P and T.

Texturally PFI located in peak metamorphic clinopyroxene and garnet from all major ore bodies contain low-salinity H_2O-CH_4 fluids (XCH_4 = 0.05-0.10). Dms include calcite, quartz and pyrrhotite. S inclusions in quartz record a complex uplift history involving a variety of fluids in the C-O-H-N-S-salt system. Isochores calculated for these inclusions constrain the uplift path to have followed an average geotherm of approximately 27°C/km assuming $P_L - P_F$

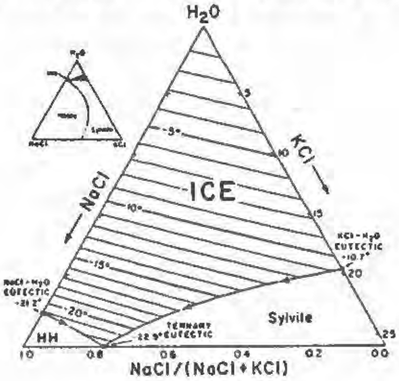
Fluid speciation calculations suggest that over the entire range of fO_2-fS_2 conditions indicated by silicate-sulfide-oxide ± graphite equilibria, $H_2O + CO_2$ generally comprised 94-100 mole % of the molecular species in the peak metamorphic (6 kb, 550°C) fluid. Other significant species were CH_4 (< 10 mole %) at low fO_2-fS_2 and H_2S (< 10 mole %) at low fO_2-high fS_2. The fluid associated with rocks bearing P inclusions is calculated to be $H_2O + CO_2$ with XCO_2 = 0.10. This composition is clearly in disagreement with the H_2O-CH_4 fluid actually present in these inclusions. Furthermore, calculations suggest that binary H_2O-CH_4 fluids could not have been in equilibrium with the metamorphic mineral assemblages at any reasonable P-T-fO_2-fS_2 conditions of peak metamorphism and imply a much more reducing environment that is indicated by mineral equilibria. This discrepancy may have resulted from reduction of CO_2 to CH_4 + H_2O due to hydrogen diffusion into H_2O-CO_2 FI during uplift. Simultaneously modeling the post-trapping behavior of hypothetical H_2O=CO_2 inclusions and enclosing rock indicates that an fH_2 gradient is established during uplift providing a driving force for diffusion of hydrogen into PFI. Alternatively, this process may have been initiated by influx of CH_4-rich fluids from an external source. These fluids are now recorded as secondary inclusions in quartz. (Authors' abstract)

HALL, D.L., COHEN, L.H. and SCHIFFMAN, Peter, 1988, Hydrothermal alteration associated with the Iron Hat iron skarn deposit, eastern Mojave Desert, San Bernardino County, California: Econ. Geol., v. 83, p. 568-587. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Full paper for abstract by Hall and Cohen, 1986, in Fluid Inclusion Research, v. 19, p. 171-172. (E.R.)

HALL, D.L., STERNER, S.M. and BODNAR, R.J., 1988, Freezing point depression of NaCl-KCl-H_2O solutions: Econ. Geol., v. 83, p. 197-202. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

The liquidus surface for the ice field was determined experimentally, and are presented graphically (figure) and as an equation based on the experimental data. The results along the NaCl-H_2O binary are significantly different from the data of Potter et al. (1978), and are believed to be more accurate. (E.R.)



HALL, G.E.M., VAIVE, J., HANNINGTON, M.D., McCONACHY, T.F. and SCOTT, S.D., 1988, Gold and associated trace elements in vent waters and suspended particulates from Southern Explorer Ridge (abst.): EOS, v. 69, p. 1501. First author at Geol. Survey Canada, Ottawa, Canada K1A 0E8.

Samples of hydrothermal vent fluids from Southern Explorer Ridge (SCHISM 1984) were analyzed for Au, As, and Sb after filtering through 0.22 um membranes. Au was recovered from polyethylene containers using Br-HCl and collected by adsorption onto activated charcoal. Extraction of the Au into MIBK was followed by analysis using graphite furnace AA. As and Sb were determined by hydride generation AA. 306°C vent waters contained 5.8 ng/kg Au, 11.4 ug/kg As, and 0.2 ug/kg Sb. 85°C waters contained 5.1 ng/kg Au, 1.6 ug/kg As, and 0.3 ug/kg Sb. Background seawater contained 3.1 ng/kg Au, 1.6 ug/kg As, and <0.2 ug/kg Sb. Additional samples collected at 291°C, 45°C, and 25°C contained background levels.

Particulates collected on the 0.22 um filters consisted of amorphous silica, barite, and anhydrite; minor sphalerite, chalcopyrite, pyrite, and calcite; and trace galena, marcasite, isocubanite, and Fe-oxides. Bulk samples of the particulates (10-20 mg) were analyzed by graphite furnace and neutron activation:

Vent	Au	As	Sb	Ag	Pb	Cu	Fe	Zn
	ug/kg			mg/kg			wt.%	
306°C	150	53	7	15	374	0.10	1.7	0.99
291	60	9	1	<10	-	-	0.9	0.27
85	450	112	22	63	1644	0.16	1.5	1.86
45	140	7	<1	2	63	0.02	0.4	0.09
25	130	17	4	8	226	0.05	1.3	0.36

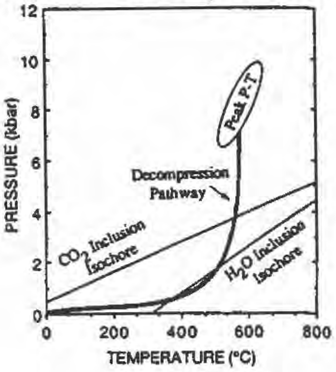
Au is strongly partitioned into suspended particulates from each vent fluid. Samples of black smoke from high-T vents at 21°N and 11°N have similar Au contents but much lower Au/Cu, Au/Fe. and Au/Zn ratios. This reflects lower Au/base metal ratios in sulfide chimneys at 21°N and 11°N compared to Explorer Ridge. (Authors' abstract)

HALSOR, S.P., BORNHORST, T.J., BEEBE, Matt, RICHARDSON, Kim and STROWD, William, 1988, Geology of the DeLamar silver mine, Idaho - A volcanic dome complex and genetically associated hydrothermal system: Econ. Geol., v. 83, p. 1159-1169. First author at Dept. Geol. & Geol. Engrg., Michigan Tech. Univ., Houghton, MI 49931.

Ore mineralogy and fluid inclusions have been used to constrain the T of ore deposition. Most of the inclusions were very small (<0.009 mm) and of limited distribution. Inclusions less than 0.001 mm could not be analyzed. Nearly all of the inclusions are simple two-phase gas-liquid with filling ratios of 0.70 to 0.85. Relatively isolated inclusions are interpreted as P in origin whereas those that clearly followed fractures are interpreted as S. Our limited data indicate that the late-stage lamellar quartz was deposited between about 200° and 240°C (not corrected for P) while the vuggy quartz was between about 170° and 220°C, suggestive of a slight cooling with time. Salinity of relatively late-stage hydrothermal fluids at DeLamar range from 2.8 to 3.8 eq. wt% NaCl. (From the authors' text by H.E.B.)

HAMES, W.E., TRACY, R.J. and BODNAR, R.J., 1988, Extreme non-linear unroofing rates following high-pressure metamorphism, southwestern New England (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A124. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Combined application of petrologic and FI techniques can yield constraints to metamorphic crustal history that are not readily available when the techniques are applied singly. This is especially true for portions of P-T paths below 500°C, where mineral assemblages typically do not reequilibrate. Garnet-biotite and garnet-biotite-plagioclase-muscovite thermobarometry of pelitic schists from the Rowe-Hawley belt of western Connecticut indicate peak Acadian P-T conditions of 575°C and 8.2 kbar. These conditions are indicated by the ellipse in the accompanying figure, which represents the 2σ uncertainty associated with that estimate. Observed densities of CO_2- and H_2O-rich FI require a nearly isothermal decompression trajectory from these metamorphic conditions. Consideration of published geochronologic data suggests this decompression was accomplished by rapid



initial upward en bloc velocity (~1 cm/yr). This episode of rapid movement appears to have been very brief, and was followed by more typical unroofing rates (0.1-0.3 mm/yr). Comparison of the observed pathway to P-T-t pathways generated by 1-dimensional thermal models suggests that uplift and erosion were accompanied by tectonic denudation, and that a high geothermal gradient was maintained by advective heat transfer. (Authors' abstract)

HANNINGTON, M.D. and SCOTT, S.D., 1988a Gold mineralization in volcanogenic massive sulfides: Modern and ancient (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 353-358. Authors at Dept. Geol., Univ. Toronto, Ontario, Canada M5S 1A1.

Fluid inclusions in Fe-poor sphalerite from sulfides containing 4.9 ppm Au at Axial Seamount give a T of 235° ± 13°C (s.d.) for Au mineralization. At a number of seafloor deposits, the variables involved in Au transport have been determined independently from analyses of vent fluids, mineral chemistry, and fluid inclusions [literature data], allowing a direct comparison of conditions of mineralzation and the average Au grade of the sulfides. High-T (350°C), low pH fluids at 21°N can carry no more than 0.1 ppb $Au(HS)_2^-$ and have precipitated sulfides with an average grade of only 0.2 ppm Au. Lower T (300°C), less acid solutions at Explorer Ridge can carry up to 1 ppb $Au(HS)_2^-$ and have precipitated sulfides with an average grade of 0.8 ppm Au. Vent fluids at 185°C to 235°C at Axial Seamount can carry up to 20 ppb $Au(HS)_2^-$ and have precipitated Au-rich sulfides averaging 4.9 ppm Au. (From the authors' abstract)

HANNINGTON, M.D. and SCOTT, S.D., 1988b, Sulfidation reactions as guides to gold distribution in modern and ancient volcanogenic massive sulfide (vms) deposits: V.M. Goldschmidt Conf.; A conference to mark the centennial year of V.M. Goldschmidt's birth, Baltimore, MD, USA, May 11-13, 1988, Publ. H.L. Barnes for the Geochem. Soc., 46 pp.

See previous item. (E.R.)

HANNINGTON, M.D. and SCOTT, S.D., 1988c, Mineralogy and geochemistry of a hydrothermal silica-sulfide-sulfate spire in the caldera of Axial Seamount (CASM site), Juan de Fuca Ridge: Eos, v. 44, p. 1485.

See previous item. (E.R.)

HANNINGTON, M.D. and SCOTT, S.D., 1988d Mineralogy and geochemistry of a hydrothermal silica-sulfide-sulfate spire in the caldera of Axial Seamount, Juan de Fuca Ridge: Canadian Mineral., v. 26, p. 603-625. Authors at Marine Geol. Res. Group, Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

Constraints on the T of formation were determined from amorphous silica solubility in sampled vent fluids (<235°C), fluid inclusions in wurtzite (up to 250°C), and published equilibrium $\delta^{18}O$ values for barite-water (185°C). The $\delta^{34}S$ values for $BaSO_4$ (+16.1 to +21.2‰), FeS_2 (+1.1 to +3.9‰), and ZnS (+4.2 to +5.7‰) indicate isotopic disequilibrium among these phases and suggest local reduction of sulfate from sea water at the site of deposition. The complex multistage history of the spire reflects growth at <300°C during mixing between higher T fluids and sea water. This process is important for the accumulation of sulfides at many sea floor vent sites and in their ancient analogs on land. (From the authors' abstract)

HANOR, J.S., 1988, Regional fluid migration and diagenetic reaction in the Louisiana Gulf Coast (abst.): EOS, v.69, p.470.

HANSEN, E., HUNT, W., JACOB, S.C., MORDEN, K., REDDI, R. and TACY, P., 1988, Evidence for CO_2-rich fluids in rocks from the "type" charnockite area near Pallavaram, Tamil Nadu (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 37-39 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 61-63). First author at Geol. Dept., Hope College, Holland, MI.

We have examined rocks for evidence indicating the concentration of carbon-dioxide in the metamorphic-fluid phase. Charnockitic rocks are cut by veins. The mineral assemblage at the edges of the vein allow us to estimate that the metamorphic fluid was nearly pure CO_2 under the metamorphic T (750-800°C) and P (6.5 = 7.5 kbars).

S or PS carbonic fluid inclusions in one vein have Tm CO_2 all within 1°C of pure CO_2. Small (up to ~20%) amounts of water may be present. Th cluster between -9°C and -18°C and hence have specific volume between 43 and 45 cm^3/mole. Isochores for the denser fluid pass through the P-T conditions deduced by Bhattacharya and Sen, 1986.

The fluid inclusions indicate that a dense CO_2-rich fluid was present at some point in the history of the charnockite. It is difficult to see how the mineral assemblages in the charnockite or its igneous precursor could have generated CO_2, hence it probably flowed in from the outside. The densities of these fluids are approximately consistent with entrapment at peak metamorphic conditions. (E.R.)

HARDIE, L.A., LOWENSTEIN, T.K. and SPENCER, R.J., 1985, The problem of distinguishing between primary and secondary features in evaporites: Sixth Int'l. Symp. on Salt, 1983, v. 1, p. 11-39.

This was abstracted in Fluid Inclusion Research, v. 18, p. 163, but an Appendix, separately authored by R.J. Spencer, entitled "The use of fluid inclusions in evaporite studies," (p. 32-36) was not mentioned. It covers P vs. S inclusions, microthermometry, crushing behavior and analysis. (E.R.)

HARNOIS, Luc, 1988, Geochemistry of the Ore Chimney Formation and associated metavolcanic rocks and gold deposits in the Flinton-Harlow area, Grenville Province, southeastern Ontario: PhD dissertation, Carleton Univ., Ottawa, ON, Canada.

Indexed under "Fluid Inclusions." (E.R.)

HARRIS, A.G., REXROAD, C.B., LIERMAN, R.T. and ASKIN, R.A., 1988, A conodont color alteration anomaly in central Indiana - Possibility of Mississippi Valley-type hydrothermal activity (extended abst.): U.S. Geol. Survey Circular 1035, p. 28-29.

HARRIS, N., BICKLE, M.J., JACKSON, D.H. and MATTEY, D.P., 1988, Constraints on advective fluid transport from carbon isotope and solid phase equilibria studies: An example from south India (abst.): Terra cognita, v. 8, p. 252. First author at Dept. Earth Sci., Open Univ., Milton Keynes, UK.

Incipient charnockite formation at Ponmudi, southern India, has been shown to be associated with shifts in carbon isotopic composition (Jackson et al., Nature, in press). The carbon isotopic front has propagated ≈ 10 cm ahead of the charnockite front into the biotite gneiss. The relative velocities of the carbon isotope front and the charnockite formation front may be calculated assuming that the propagation of the fronts is due to infiltration of a CO_2-rich fluids. The velocity of the carbon isotopic front is a function of the fluid flux rate, the CO_2 content of the fluid and the graphite content of the biotite gneiss (cf (Bickle & McKenzie, 1987, Contrib. Mineral. Petrol. 95, 384-392). The velocity of the charnockite front is also a function of the fluid flux rate as well as the difference in CO_2 content of the fluid across the front and in the volume rate of water production by the charnockite-forming reaction. Using mineral data in Hansen et al., (1987, Contrib. Mineral. Petrol. 96, 225-244) we calculate that the carbon isotope front will propagate about twice as fast as the charnockite-forming front. The small separation of the carbon isotopic and the charnockite fronts suggests that the total transport distances are only of the order of the separation of the fronts, i.e., cm. If infiltration is the cause of these phenomena the processes were very localized and involved relatively small volumes of fluids. (Authors' abstract)

HARRISON, W.J., HOLZWARTH, W.J., SUMMA, L.L. and HUANG, W.-L., 1988, Aluminum contents of authigenic quartz: A possible indicator of paleo fluid chemistry? (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A391. First author at Dept. Geol. & Geol. Engrg., Colorado Sch. Mines, Golden, CO 80401.

Analyses of trace metals, Al, Fe, and Ti, in authigenic quartz from a variety of sandstones from different geographic locations and geologic ages have been made using the electron microprobe. Concentration ranges measured, with detection limits shown parenthetically, are up to 3000 ppm Al (50 ppm), 600 ppm Fe (30 ppm) and 100 ppm Ti (20 ppm).

High aluminum concentrations appear to quench cathodoluminescence in quartz, and many quartz overgrowths show zonation in luminescence which correlates with zonation in aluminum concentration. Zonation presumably reflects multiple episodes of quartz growth.

High resolution transmission electron microscopy shows no evidence for inclusions of aluminosilicate minerals in the quartz which could account for such high aluminum concentrations. Aluminum is probably substituted for Si^{4+} in the quartz structure, with charge balance being achieved by either coupled substitution of a monovalent ion such as H^+ or Li^+, or by an oxygen vacancy. Both mechanisms, as well as the range of aluminum concentrations we have measured, are documented in the solid state chemistry literature.

A strong correlation exists between the presence of kaolinite as a coexisting authigenic mineral and aluminum concentrations in quartz of 1500-3000 ppm. When illite is the coexisting authigenic phase, quartz overgrowths have aluminum concentrations of less than 700 ppm. At this time our hypothesis is that the paleo-fluid chemistry, in particular pH, from which the authigenic clays and quartz precipitated is reflected in the aluminum content of the quartz. Experimental studies, involving the synthesis of quartz from variable pH solutions are underway to attempt to calibrate these petrographic observations. (Authors' abstract)

HART, Dale, 1986, An evaluation of fluid inclusion techniques as tools in mineral exploration as applied at the Yellow Aster gold mine, California: MS thesis, Univ. Alaska, 193 pp.

Fluid inclusions have the potential to provide useful data during a minerals exploration program. Three fluid inclusion techniques were applied at the former Yellow Aster Au mine in California, which produced 500,000 troy ounces of Au until 1923. The techniques evaluated independently were; decrepitation linked induction coupled plasma emission spectrographic analysis (DICP), fluid inclusion mapping and fluid inclusion microthermometry.

Approximately 100 analyses of quartz revealed DICP to be an inappropriate technique at Yellow Aster. Fluid inclusion mapping of 100 thin sections was a relative success and highlighted the increased inclusion abundance in quartz associated with Au mineralization. Conclusions based on greater than 1200 microthermometric measurements suggest Au-sulfide mineralization is a result of fluid boiling. Successive generations of inclusions record the loss of 20 mole % CO_2 from the fluid regime and the overall cooling from 330°C to 240°C. Redox reactions controlled Au deposition in the near surface zones. (Author's abstract)

HASELTON, H.T., Jr., CYGAN, G.L. and d'ANGELO, W.M., 1988, Chemistry of aqueous solutions coexisting with fluoride buffers in the system K_2O-Al_2O_3-SiO_2-H_2O-F_2O_{-1} (1 kbar, 400°-700°C): Econ. Geol., v. 83, p. 163-173.

HASSANIPAK, A.A. and WAMPLER, J.M., 1988, A search for initial $^{40}Ar/^{36}Ar$ ratios of Permian rock salt from the Palo Duro Basin, Texas (abst.): Chem. Geol., v. 70, p. 37. Authors at Sch. Geophys. Sci., Georgia Inst. Tech., Atlanta, GA 30332, USA.

Some inclusion-rich halite crystals from bedded salt of the Palo Duro Basin, Texas, have $^{40}Ar/^{36}Ar$ ratios slightly less than the ratio in modern atmospheric argon. We interpret the low ratios to be a result of entrapment of argon from the Permian atmosphere. Support for this interpretation comes from sequential potassium-argon analyses obtained by dissolving salt specimens in a series of steps. Correlation of the $^{40}Ar/^{36}Ar$ and $^{40}K/^{36}Ar$ ratios obtained in such sets of analyses indicates that radiogenic argon formed in the salt since the Permian period has largely remained very near where it was formed. There is wide variability in the distribution of ^{36}Ar within the salt specimens, and the data suggest that most of the argon in the inclusion-rich single crystals was trapped when the crystals formed. Much more work will be needed to establish whether the initial argon in such salt specimens is isotopically uniform from place to place. If such uniformity can be established, then it would seem likely that argon from the Permian atmosphere had been trapped in the salt without having been affected by isotopic fractionation or by addition of radiogenic argon prior to entrapment. (Authors' abstract)

HASTINGS, J.S. and HARROLD, J.L., 1988, Geology of the Beal gold deposit, German Gulch, Montana, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 207-220. First author at Pegasus Gold Inc., 255 West Moana Lane, Suite 108, Reno, NV 89509.

The Beal deposit, a low-grade, bulk mineable precious metal reserve hosted by late Cretaceous continental clastic sedimentary rocks metamorphosed by granodiorite and diorite intrusions, occurs within the Cordilleran fold and overthrust belt of southwestern Montana. Pegasus Gold Corporation acquired the principal properties in late 1980 and to date has defined 9.2 million metric tons grading 1.509 gm/ton (0.044 oz/ton) Au, on the west.

Sulfide and precious metal mineralization occurs primarily as disseminations within favorable lithologic horizons, and to a lesser extent in narrow crosscutting veins containing quartz, chlorite and/or carbonate. Sulfide mineralization, though temporally and spatially related to precious metals, typically contains only trace amounts of Au and Ag.

Au occurs in the free state and in minor amounts with Pb-Bi tellurides. The Au to Ag ratio is approximately 1:1. Gangue minerals associated with Au mineralization include sulfides, quartz, calcite, chlorite, sericite and various clay minerals. Preliminary ore microscopy and petrographic studies indicate that precious metal mineralization, with a K/Ar age date of 71.8 m.y., followed the crystallization of sulfide minerals, and thus occurred when S to Fe ratios were low. The paragenesis of mineralization has been defined as pyrrhotite, pyrite, molybdenite, arsenopyrite, chalcopyrite, telluride minerals and free Au.

An initial study of fluid inclusions suggests that fluids migrating through the more permeable rocks during thermal metamorphism contained a magmatic component that may have been derived from a buried source. Consequently, mineralizing fluids are thought to have been introduced into the system during the metamorphic event. (From the authors' abstract by E.R.)

Quartz and calcite vein material have at least three populations of inclusions: CO_2-rich, salt saturated, and low salt. The CO_2-rich fluids occur in S inclusions with consistently high Th (+325°C) and probably record emanations from a magma.

Highly saline inclusions, on the other hand, are characterized by lower T (180°-200°C) whose irregular shapes and consistency of L/V ratios[sic] suggest that they may have existed on a regional scale. The high T group of saline inclusions (230°-300°C) could represent the same fluids as the low T group above but heated by the local thermal anomaly responsible for the CO_2-rich vapors. Low-T (<110°C), low-salinity, single phase inclusions, the third type, probably record a more recent event that interacted with circulating ground waters on a local scale. This study suggests that mineralizing fluids may have been derived from a buried source and were introduced into the system during the metamorphic event. (From the authors' text)

HASZELDINE, R.S., SAMSON, I.M. and CORNFORD, C., 1984, Quartz diagenesis and convective fluid movement: Beatrice oil field, UK North Sea: Clay Minerals, v. 19, p. 391-402. First author at Stratigraphic Lab., Britoil, 150 St. Vincent St., Glasgow G2 5LJ, Scotland.

The extent of diagenesis in Lower Jurassic shoreline sandstones of the Beatrice oil field was controlled primarily by their detrital clay content. Sandstones rich in detrital clay had low depositional permeabilities: these show preservation of detrital feldspars to the present day and have no extensive diagenetic quartz overgrowths. Sandstones poor in detrital clay had high permeabilities and show large quartz overgrowths as part of a normal subarkosic diagenetic sequence. Such quartz occurs preferentially below, but not above, impermeable mudstones. These low- and high-permeability features suggest that pore-fluid flow was important during diagenesis. Fluid inclusions trapped in diagenetic quartz overgrowths formed between 68° and 94°C. This silica was probably supplied in solution from the T-driven illitization of smectitic clays surrounding these sandstones deeper in the basin. Fluid volumes from clay dewatering, from mechanical compaction, or from influx of overlying sea water were too small to transport diagenetic silica volumes. Silica-rich fluids were probably transported up-dip by convective cells within the sandstones and authigenic quartz precipitated as these fluids cooled. This episode of quartz diagenesis could have been completed within 1.6 x 10^6 yr if fluid velocities were 3.1 m/yr. Similar convective fluid flows could have transported the fluids responsible for secondary porosity development and the hydrocarbons expelled from mudstones later in the basin burial history. (Authors' abstract)

HAWKE, Alan, HAWKE, Michele, Van LEEUWEN, Theo and HARTLEY, Mark, 1988, The Kelian gold deposit, east Kalimantan, Indonesia. From discovery to feasibility (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 150-152. Authors at P.O. Box 420 Kby, Jakarta Selatan, Indonesia.

Present fluid inclusion data indicates that there were at least two very distinct fluid types present during mineralization at Kelian. One shows characteristics of epithermal-type deposits and the other shows characteristics of porphyry-type mineralization. The controls on Au mineralization are also unresolved. (From the authors' abstract)

HAYNES, F.M., 1988, Fluid-inclusion evidence of basinal brines in Archean basement, Thunder Bay Pb-Zn-Ba district, Ontario, Canada: Can. J. Earth Sci., v. 25, p. 1884-1894. Author at Geol. Dept., Exxon Co. USA, P.O. Box 5025, Thousand Oaks, CA 91359, USA.

Fluid inclusions from three quartz-galena-sphalerite-barite-calcite veins in the Thunder Bay district of western Ontario contain liquid + vapor ± halite and homogenize by vapor disappearance or halite dissolution at T of 90-200°C. Cyclically frozen L + V (type I) inclusions undergo four melting events upon gradual warming (initial melting at -55 to -46°C; ice disappearance at -30.2 to -25.4°C; inversion of hydrohalite to halite at -8.0 to 0.7°C; and halite melting at 14.0 to 56.3°C. L + V + halite (type II) inclusions behave similarly but have higher Tm ice (-27.2 to -21.7°C) and Tm halite (105-203°C). Scanning electron microscopy and energy dispersive analysis of fluid-inclusion-derived decrepitates indicate that the solutes consist of NaCl > $CaCl_2 \gg$ KCl and are consistent with the low-T phase observations in that they define two distinct populations based on $CaCl_2/(CaCl_2 + NaCl)$ ratios.

The T and compositional trends defined by the inclusion results are similar to those documented for basinal brines and from fluid inclusions in MVT ore deposits. The Thunder Bay veins cross the basal unconformity of the Middle Proterozoic Sibley basin and extend into Archean basement granites, such that the fluid inclusions results provide direct evidence that basinal waters infiltrated basement rock in western Ontario. The inclusion fluids and associated mineralization are thought to result either from dewatering of the Sibley basin during Keweenaw age rifting or from the introduction of exotic Paleozoic basinal waters when the Michigan basin extended over the region. (Author's abstract)

HAYNES, F.M. and KESLER, S.E., 1988, Compositions and sources of mineralizing fluids for chimney and manto limestone-replacement ores in Mexico: Econ. Geol., v. 83, p. 1985-1992. First author at Exxon Co. USA, P.O. Box 5025, Thousand Oaks, CA 91359.

Analysis by SEM-EDA of decrepitates from Santa Eulalia, Naica, and Zimapan chimney and manto deposits indicate Na-dominated brines with highly variable KCl and $CaCl_2$. Naica has Na>K>Ca (consistent with a magmatic source); Santa Eulalia has Na>Ca>>K (similar to basinal waters). Zimapan = intermediate. (E.R.)

HAYNES, F.M., STERNER, S.M., and BODNAR, R.J., 1988, Synthetic fluid inclusions in natural quartz. IV. Chemical analyses of fluid inclusions by SEM/EDA: Evaluation of method: Geochim. Cosmo. Acta, v.52, p.969-977. First author at Dept. of Geol. Sci., Univ. of Michigan, Ann Arbor, MI 48109-1063 USA.

The compositions of individual synthetic fluid inclusions in the systems NaCl-KCl, NaCl-$CaCl_2$ and NaCl-KCl-$CaCl_2$ have been semi-quantitatively determined by energy dispersive analysis of precipitates produced during thermal decrepitation. Inclusions containing known mixtures of 20 wt.% total salinity were synthesized by healing fractures in natural quartz at 600-700°C and 5-7 kbars for 7-10 days. The two-phase dm-free inclusions have Th at 170-250°C, began to decrepitate after about 100° of overheating and by 360-420°C a significant number of decrepitates had formed on the polished surface. Peak heights generated by EDA (raster mode) of these decrepitates were standardized using both single and mixed salt standards evaporated to dryness in a vacuum. Although the mixed salt standards better approximated the decrepitate compositions, difficulties were encountered in producing micronscale homogeneity and the single salts yielded more reliable results.

Eight different solutions of 20-23 wt.% total salinity were run and in all the samples the average compositions of 10-20 discrete, single inclusion decrepitates fell within 6 wt.% (0.2 to 5.2) of the actual composition, suggesting that the decrepitates were chemically representative of their precursor inclusions. However, not all decrepitates analyzed provided similarly accurate results. Electron mapping revealed that fracture-aligned decrepitates were often chemically inhomogeneous and thus had to be avoided. A sample decrepitated at 500°C yielded spurious results suggesting that chloride volatility may become a significant problem when $T > 450°C$ are required for decrepitation. Decrepitates with diameters between 10 and 30 μm yielded more consistent and accurate results than smaller or larger decrepitates on the same samples. (Authors' abstract)

HE, Mingyou, 1988, Zircon inclusions and their homogenization identification in melting experiment: J. Chengdu College of Geol., v. 15, no. 3, p. 32-37 (in Chinese; English abstract). Author at Chengdu College of Geology.

Most zircon crystals in granitic rocks contain [melt] inclusions, which still [contain the] original magmatic medium and can be used for petrogenetic and thermodynamic study. This paper describes the characteristics of the inclusions and method of their identification in homogenization melting experiment. (Author's abstract)

HE, Zhili, 1988, Main achievements in the study of inclusions mineralogy in China: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 201-202. Author at Beijing Univ. of Iron & Steel Tech., Beijing, China.

See He, Zhili, 1986, Fluid Inclusion Research, v. 19, p. 177-178. (E.R.)

HEARN, P.P., Jr., BELKIN, H.E. and SUTTER, J.F., 1988, Tectonically induced fluid migration in sedimentary basins: A new factor to be considered in the assessment of thermal history (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A330. Also in U.S. Geol. Survey Open-File Report 88-0585, p. 3-4. Authors at U.S. Geol. Survey, Reston, VA 22092.

A growing body of evidence now suggests that large volumes of fluids were expelled from deeply buried foreland basin sediments during plate collisions along the margins of the North American craton. Hot (100-200°C) and saline (10-20 wt% NaCl eq.) fluids apparently were driven out of peripheral basins and migrated considerable distances onto the craton during geologically brief periods of time. Temporally asynchronous but analogous fluid-migration events are believed to have occurred along the entire extent of the Marathon, Quachita, Appalachian, and Caledonide orogenic belts. Similar events are believed to have occurred in the Alberta Basin and in tectonically active basins of the continental interior. These conclusions are supported by a large body of data, including K-Ar and $^{40}Ar/^{39}Ar$ analyses of secondary minerals, paleomagnetic data, computer simulations of basin paleohydrology, fluid-inclusion analyses, and petrographic observations. The large-scale transfer of heat associated with the upward migration of hot basinal fluids is capable of producing abnormally high thermal gradients. While these anomalous gradients are geologically short lived, they persist long enough to be reflected in fluid-inclusion, conodont-alteration, fission-track, and vitrinite-reflectance data. Also, K-metasomatism commonly associated with brine migration may produce increased ordering in illite-smectite assemblages. As a consequence, some depth-of-burial estimates based on these thermal indicators may be erroneously high. In numerous instances, the lack of agreement between stratigraphic estimates of burial depth and estimates based on thermal-maturity indicators has been cited as evidence that stratigraphic estimates are erroneously low. Clearly, the assumption that burial-induced heating is the sole influence on the thermal history of sediments is often not valid, and models that ignore thermal overprints from fluid migration events may lead to significant errors. (Authors' abstract)

HEARN, P.P., SUTTER, J.F., BELKIN, H.E., and KUNK, M.J., 1988, Authigenic K-feldspars: An indicator of the time of migration and thermochemical character of crustal fluids mobilized by tectonic activity (abst.): EOS, v.69, p.470-471. First author at USGS, MS-957, Reston, VA 22092.

See previous items (E.R.).

HEBEDA, E.H., SCHULTZ, L. and FREUNDEL, M., 1987, Radiogenic, fissiogenic and nucleogenic noble gases in zircons: Earth & Planet. Sci. Letters, v. 85, no. 1-3, p. 79-90.

HEDENQUIST, J.S., IZAWA, E., MARUMO, K., SASAKI, A. and AOKI, M., 1988, Ore fluids for gold mineralization of acid-leached siliceous rocks in the Nansatsu district (abst.): Mining Geol., v. 38, no. 1, p. 78 (in Japanese; translation courtesy S. Takenouchi).

Hydrothermal solutions of the Nansatsu hot spring-type Au deposits were studied from the standpoint of fluid inclusion and stable isotopic composition. Th of fluid inclusions in quartz were in the range 190°-200°C for the Iwato and 200°-240°C for the Kasuga. Salinity was <1 wt.% in general, but high salinity fluid inclusions were found from a breccia zone near the Kasuga. δ^{34}S of alunite from the acid alteration zone was +30‰, suggesting that alunite crystallized from solutions having δ^{34}S = ~ 0‰ at ~200°C. δ^{18}O of quartz was +10‰, indicating that δ^{18}O of solution ranged -2 ~ +2‰. δ^{18}O of solution calculated from δ^{18}O of clay minerals was also ~0‰ and δD indicated that of meteoric water. It is concluded that hydrothermal solutions which have brought the silicification and mineralization of the Nansatsu-type Au deposits were deeply circulating meteoric water reacted with high-T rocks. (Authors' abstract)

HEDENQUIST, J.W., MATSUHISA, Y., IZAWA, E., MARUMO, K., AOKI, M. and SASAKI, A., 1988, Epithermal gold mineralization of acid-leached rocks in the Nansatsu district of southern Kyushu, Japan: Bicentennial Gold 88, Geol. Soc. Australia Abstract Ser. no. 22, p. 183-190. First author at DSIR, Chem. Div., Private Bag, Taupo, New Zealand.

Includes data on Th and Tm of quartz from Iwato and Kasuga, from the literature and new work. Th ranges widely but average at Iwato = 190-200°C and 200-240°C at Kasuga. Most Tm ice values range between -0.2 and -0.6°C, but one sample from breccia marginal to the Kasuga ore body has many vapor-rich inclusions, some liquid-rich with NaCl dms, and a few with Tm ice of ~-8°C. Many of these have Th(L) or Th(V) of 250 to >350°C. Also reports data on S, O and H isotopes, and interprets all in terms of chemistry of alteration and exploration tools. (E.R.)

HEIN, U.F., BRINCKMANN, J. and LEHMANN, B., 1988, The bastnaesite-monazite deposits of Gakara/Burundi: A SEM-EDS study of daughter crystals in fluid inclusions: Presented during the 66th Ann. Meeting of the German Min. Soc. in Bonn, 1988, but submitted too late for inclusion in the printed abstract volume.

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 granitic pegmatites are dated at 969 ± 8 Ma (2). The vein- and stockwork-type mineralization crosscuts these pegmatites, and the bastnaesite itself has been dated at 587 ± 4 Ma (3). Bastnaesite, minor sulfides, 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 (4)(5).

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 as two types:

a) type 1 containing predominantly liquid CO_2. In a few cases a small rim of aqueous solution is visible although probably always present. Tiny dxls are rare; and

b) type 2 multiphase inclusions made up of highly saline aqueous fluids. These contain an aqueous solution, a gas bubble, commonly an opaque mineral and up to seven transparent solids, the number of which is a function of the inclusion size.

A number of dxls and trapped minerals were identified in opened type 2 inclusions by their optical properties, solubility behavior during heating stage treatment, and semiquantitative SEM-EDS techniques. The most important soluble salt minerals, in order of their abundance, are halite (NaCl), arcanite (K_2SO_4), and sylvite (KCl). This is only the second reported occurrence of arcanite as a daughter phase (6). Siderite is restricted to early inclusions in quartz and shows characteristic etched faces probably resulting from retrograde solubility. Anhydrite commonly shows poorly developed prismatic crystals. The opaque mineral is pyrite, as faceted cubes or dodecahedrons. Hexagonal flakes of muscovite occur as trapped crystals. The inclusion paragenesis listed above represents the fluids responsible for the early potassic alteration-mineralization stage, and the aqueous fluid composition resides in the system Na-K-(Fe-Ca)-Cl-S. Other observed dxls and trapped crystals are listed in a table. (Authors' abstract)

(1) Hein, U.F. (1988), Report 102966, B 1.13-6274/87, BGR Hannover.

(2) Brinckmann, J. et al. (1987), 14th Coll. African Geology, Abstr. Vol., CIFEG Occ. Publ. 1987/12: 160-161.

(3) Nakai, S. et al. (1988), Amer. Mineral. (submitted).

(4) Aderca, B.M. & R. Van Tassel (1971), Acad. Roy. Sci. d'Outre-Mer, Class. Sci. Nat. Méd., N.S., XVIII-5: 4-117.

(5) Van Wambeke, L. (1977), Mineral. Deposita 12: 373-380.

(6) Metzger, F.W. et al. (1977), Econ. Geol. 72: 141-152.

HEINRICH, C.A., ANDREW, A.S., WILKINS, R.W.T. and PATTERSON, D.J., 1988, A fluid inclusion and stable isotope study of synmetamorphic copper ore formation at Mount Isa (abst.): Geol. Soc. Australia Abstract Series No. 21, p. 183-184. First author at CSIRO Div. Min. Physics & Mineral., North Ryde.

Fluid inclusions in quartz and dolomites were studied by microthermometry, Raman microspectrometry, and semiquantitative electron microprobe analysis of inclusion salts. Two types of aqueous inclusions are restricted to dolomitic breccia: Group 1: A $CaCl_2$-rich brine with a cation ratio Na:Ca:K:Mg 30:10:3:1 and salinity (25 wt % NaCl eq) similar to recent Salton Sea geothermal brines; Th 190-290°C; and Group 2: A low-salinity fluid with 10-20 mol % CO_2; Th 270-290°C. These two types are intimately associated in the same crystals and have probably been simultaneously trapped.

Siliceous alteration which has overprinted dolomitic breccia contains Group 3 inclusions, NaCl-rich with Na:Ca:K:Mg 300:10:30:1, CH_4 probably $>CO_2$; Th 140-180°C. Textures suggest that a higher-salinity (10-20 wt % NaCl eq) and a lower-salinity (4-9 wt % NaCl eq) variants of this NaCl-rich fluid bracket the main stage of chalcopyrite introduction. There are no low-density vapor inclusions indicative of fluid boiling at any stage, but rare high-density CH_4 ($-CO_2$)-rich carbonic inclusions occur in a few samples in association with NaCl-rich aqueous inclusions with slightly higher than average Th.

These inclusion data and isotopic studies (O, H, C) are combined to formulate a working hypothesis for syntectonic and synmetamorphic fluid/rock interaction and ore formation. (From the authors' abstract)

HEIZLER, M.T. and HARRISON, T.M., 1988, Multiple trapped argon isotope components revealed by $^{40}Ar/^{39}Ar$ isochron analysis: Geochim. Cosmo. Acta, v.52, p.1295-1303.

HELGESON, H.C., ed., 1987a Chemical transport in metasomatic processes: D. Reidel Pub. Co., Dordrecht, 782 pp.

Individual chapters are abstracted in this volume. (E.R.)

HELGESON, H.C., 1987b Application of moderation theorems to metasomatic processes, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 189-238. Author at Dept. Geol. & Geophysics, Univ. California, Berkeley, CA 94720, USA.

Moderation theorems can be used to predict the consequences of perturbing a system from a stable equilibrium state to an adjacent nonequilibrium state. Although in the absence of external constraints, the moderation theorem known as the Le Chatelier-Braun principle affords accurate prediction of the consequences of such perturbations in closed systems, it is not applicable to many reactions of geologic interest in open systems. As demonstrated by De Donder (1933), De Donder and Van Rysselberghe (1936), and Prigogine and Defay (1954), constraints imposed by the second law of thermodynamics commonly lead to contradictions of the Le Chatelier-Braun principle in the latter systems. Derivation of moderation criteria for simultaneous independent hydrolysis reactions for minerals indicates that the criteria can be applied directly to overall dehydration/decarbonation reactions in metasomatic processes. Although moderation with respect to the mole fraction of a perturbed component always occurs in fluids in which ideal mixing takes place, whether or not moderation of metasomatic reactions takes place with respect to addition to, or removal from the fluid of a small amount of a given component such as CO_2 or H_2O depends on the stoichiometry of the reaction. De Donder's fundamental inequality (De Donder, 1922) can be used to calculate limiting fluid compositions for moderation with respect to addition or removal of such components. Isothermal-isobaric perturbation of equilibrium in the vicinity of these limiting compositions may led to dramatic changes in the relative masses of reactants and products. Some CO_2-H_2O metasomatic reactions will not moderate in response to changes in the mass of either CO_2 or H_2O in the intermediate range of $X(CO_2)$.

Explicit recognition of moderation constraints in open systems and application of moderation theorems to both experimental and field observations facilitates considerably interpretation of phase relations and correlation of trends in the relative masses of metasomatic minerals to changes in T, P, and fluid composition. (Author's abstract)

HELGESON, H.C. and SHOCK, E.L., 1988a Role of oxidation/reduction reactions in the hydrothermal transport and deposition of petroleum (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A95. First author at Dept. Geol. & Geophys., Univ. California, Berkeley, CA 94720.

Thermodynamic calculations indicate that oil field brines are in metastable equilibrium with both petroleum and the diagenetic mineral assemblages in hydrocarbon reservoirs, but out of equilibrium with methane and graphite. The composition of the hydrocarbon liquid apparently controls the fugacity of oxygen and the concentrations of carboxylic acids in the aqueous solution. The activity of CH_3COOH in the aqueous phase increases with increasing carbon number of the hydrocarbon liquid, fugacity of oxygen, and/or T. Thermodynamic calculations also indicate that metastable equilibrium at reservoir T of the order of 100-180°C among petroleum and oil field brines in the presence of albite, quartz, and kaolinite, or illite, quartz, and kaolinite is accompanied by <60 to >6,000 ppm total acetate ($CH_3COOH + CH_3COO^-$) in the aqueous solution, which may increase dramatically with decreasing T, depending on the mineral assemblage and the composition of the hydrocarbon phase. Analytical data reported in the literature indicate that total acetate has been detected in oil field brines at concentrations up to ~5000 ppm. The acetic acid is apparently in metastable equilibrium with dissolved carbonate species. It follows that petroleum may be the source of carbon in calcite and dolomite cements. Hydrothermal precipitation of petroleum from oil field brines is favored by decreasing fugacity of oxygen such as that accompanying reaction of the brines with detrital biotite and magnetite to form authigenic siderite, K-feldspar, and/or pyrite. In contrast, oxidation of kerogen with burial in source rocks increases the concentration of acetic acid in the aqueous phase. It thus appears that oxidation-reduction reactions involving aqueous solutions may have a significant effect on the origin, transport, and deposition of oil and gas in hydrocarbon reservoirs. (Authors' abstract)

HELGESON, H.C. and SHOCK, E.L., 1988, Kinetic and thermodynamic constraints on phase relations among minerals, petroleum, and aqueous solutions in diagenetic processes (abst.): Chem. Geol., v. 70, p. 78. First authors at Dept. Geol. & Geophys., Univ. California, Berkeley, CA 94720, USA.

Thermodynamic calculations strongly support experimental observations (Palmer and Drummond, 1986) indicating that carboxylic acids may persist metastably in oil field brines over long periods of geologic time. Carboxylic acids in the brines are apparently in metastable equilibrium with both petroleum and the diagenetic mineral assemblages in hydrocarbon reservoirs. It appears that the petroleum composition buffers the fugacity of oxygen and the concentration of acetic acid in the coexisting aqueous phase. The calculations indicate that methane and graphite are not in equilibrium with either petroleum or the aqueous solution, and that carbonate solubilities in oil field brines are controlled by the concentrations of carboxylic acids. (Authors' abstract)

HEMLEY, J.J., CYGAN, G.L. and d'ANGELO, W.M., 1987, Sulfide solubilities in buffered systems from 400 to 600°C and 0.5 to 2 kb and depositional implications (abst.), in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 755. Authors at U.S. Geol. Survey, 959 National Center, Reston, VA 22092, USA.

Experimental studies have been conducted on the solubility of Fe and other base metal sulfides in chloride solutions equilibrated with a synthetic quartz monzonite plus assemblages in the Fe-Cu-S-O system. Extraction vessel and cold-seal techniques were used. Most experimentation was on the pyrrhotite-pyrite-magnetite buffer for fixing fS_2 and fO_2, but K-feldspar-muscovite-quartz controlled hydrogen ion activity in all cases. At 1 m total chloride and 1 kb, Fe concentrations in a system containing only Fe as the base metal were 1,000 ± 150, 7,000 ± 700, 12,400 ± 1,000 and 14,000 ± 1,200 ppm at 400, 500, 600, and 700°C respectively. At 500°C different Cl^- concentrations, P, and additional buffers in the Fe-Cu-S-O system were investigated. Pb and Zn concentrations at 500°C and 1 kb on po-py-mt in a system containing galena, sphalerite, molybdenite, silver sulfide and chalcopyrite, were both about 2,450 ± 500 ppm, and Fe was decreased to about 4,100 ppm. Cu, Mo and Ag were present in very low to trace concentrations, on the order of 10 to 100 ppm. Major controls on mineral solubilities are total chloride and P, as well as T. Although the data show considerable variation, at 2 m Cl^-, 500°C and 1 kb, Fe concentration is increased to ~20,000 ppm in the pure Fe system. Similarly, at 1 m Cl and 2 kb it is decreased to about 1,700 ppm and at 0.5 kb it is increased to about 14,000 ppm. Similar relations were observed for Pb and Zn.

The changes with P are especially important to ore transport. Metals could be carried over long distances on a decreasing P gradient so long as the T decrease were not sufficient to more than cancel the P effect. Such a condition could be approximated in a near-adiabatic transport, cooling path. Competiton between Fe and other base metals for chloride ligands is also important. Mineralizing solutions carrying relatively high base metals and low Fe, on passing through Fe sulfide or oxide-bearing rocks would dissolve Fe and deposit base metals, producing sulfide replacement and zoning relations that are characteristic of many sulfide ore deposits. (Authors' abstract)

See also Fluid Inclusion Research, v. 20, p. 164-165. (E.R.)

HENDERSON, J.R., HENDERSON, M.N. and WRIGHT, T.O., 1988, Crack-seal texture in columnar-quartz veins: Implications for fluid pressure, time of vein formation and strain partitioning (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A58. First author at Geol. Survey Canada, Ottawa, Ontario K1A 0E8, Canada.

Numerous examples of episodic hydraulic fracturing and sealing have been documented for fibrous veins showing inclusion-band fabric since Ramsay (Nature, 1980) proposed the crack-seal mechanism of rock deformation. Here we describe an unusual solid-incluson band fabric exhibited by isolated and dispersed 1-2 cm dia. columnar quartz crystals composing 10-20 cm wide bedding-parallel auiferous veins in the turbiditic flysch of the Cambro-Ordovician Meguma Group, Nova Scotia. The columnar crystals tend to be oriented normal to the vein walls and display Brazil twins. Viewed along the surface parallel to bedding, the crystals show hexagonal sections with dark-grey solid-inclusion-rich centers and milky-white fluid inclusion-rich rims, forming an interlocking honeycomb fabric. Viewed in profile, the dark centers of quartz crystals are composed of clean quartz laminae bounded by white micas forming solid-inclusion bands. The 0.05-0.1 mm thick quartz laminae tend to be aligned parallel to the vein walls and terminate within large tapered crystals which have an outer zone of milky quartz.

These observations lead us to conclude that: (1) the solid-inclusion banded quartz resulted from episodic hydraulic fracturing and incremental growth of crystals dispersed in the fluid-filled fracture; (2) the crystals initially were attached to both walls of the fracture, but the tapered crystals indicate that subsequent fractures occurred antiaxially on their larger ends; (3) between pulses of hydraulic fracturing fluid P equaled lithostatic P and the space between quartz crystals was occupied by an aqueous fluid; (4) the milky quartz displaced the fluid by growing in optical continuity with the solid-inclusion banded quartz, and (5) following vein formation, folding was accommodated by partitioning of strain between bedding-parallel shear in the wall rocks, and mainly rigid rotation of the veins which preserved their primary fabric. (Authors' abstract

HENN, U., 1988, Studies of emerald from Swat valley, Pakistan: Z. Dt. Gemmol.

Ges., v. 37, no. 3/4, p. 121-127 (in German; English abstract).

Physical and chemical properties as well as microscopical features of emeralds from Swat valley in Pakistan are described. Refractive indices, birefringence and density are relatively high referring to relatively high contents of chromium and iron. Talc, calcite/dolomite, pyrite, chromite and molybdenite were analyzed as mineral inclusions beside liquid feathers, two- and three-phase inclusions and growth tubes. (Author's abstract)

HENNET, R.J.-C., CRERAR, D.A. and SCHWARTZ, Jeffrey, 1988, Organic complexes in hydrothermal systems: Econ. Geol., v. 83, p. 742-764. First author at Dept. Chem., Woods Hole Oceanographic Inst., Woods Hole, MA 02543.

Electrochemical techniques (two different polarographic techniques and the ion specific electrode method) were used to measure the equilibrium constants of lead (II) organic complexes up to 90°C. The data are extrapolated to 200°C. The equilibrium speciation model EQBRM was used to calculate the significance of organic complexing in Na-Ca-Cl-bearing brines, from 50° to 200°C, by comparing total organic complexing to total chloro complexing with lead (II) and zinc (II). The significance of organic complexing in hydrothermal brines depends mostly on the solubility of the calcium (II) organic salts, the concentration of calcium in solution, the thermal stability of the organic species, and the acidity of the ligands' binding groups. The model showed that acetate (or other soluble carboxylates) complexes with lead (II) and zinc (II) can predominate over chloro complexes under neutral to slightly acidic pH conditions when present at concentrations which have been observed in hydrothermal brines. A minimum concentration of about 10^{-3} m of organic ligand is necessary for species such as oxalate to complex base metals in Na-Ca-Cl-rich brines in a signficant way. This concentration (10^{-3} m) is one or more orders of magnitude supersaturated with respect to Ca oxalate. The low calcium salt solubility also prevents ligands, such as phthalate, anthranilate, picolinate, dipicolinate, 1, 10 phenanthroline, and thiosalicylate, to be of potential importance for base metal transport in Ca-rich hydrothermal fluids. (Authors' abstract)

HENRY, A.L., 1988, Alteration of organic matter in the Viburnum Trend lead/zinc district of southeastern Missouri: MS thesis, Univ. Toronto.

Microscopic petrographic examination of organic mater, including identification and spectrophotometric reflectance analysis of over 5000 organic particles, was performed using both transmitted and reflected light on kerogen concentrate mounts and polished petrographic thin sections for 52 samples from the Bonneterre Formation. The samples were collected along a drill hole section perpendicular to the Viburnum Trend through the south end of the Buick mine property, extending 24 km to the east and 120 km to the west of the ore deposits. Bulk organic elemental analyses (C, H, O, N) were also performed on the kerogen concentrates from 21 key samples. These studies demonstrated that bitumen has been generated from kerogen within the Bonneterre Formation, but only within about 10 km of the Viburnum Trend. Some of this bitumen accumulated within the kerogen and in pores in the surrounding dolostone, and later solidified due to the effects of thermal maturation and water-washing. At some locations, notably in the "Whiterock" diagenetic facies and in the ore deposits, the solid bitumen has been further degraded by microbial activity.

Primary organic matter (kerogen), consisting of identifiable remains of algae (alginite) and amorphous kerogen of presumed marine algal-bacterial origin, is distributed throughout the Bonneterre Formation along dolomite grain boundaries, but is most concentrated in occasional, <10 mm thick, organic-rich lamellae and stylolites. In the vicinity of the Viburnum Trend, significant quantities of solid bitumen have accumulated in pores in the dolostone adjacent to these concentrations of kerogen. Bitumen also impregnated some of the alginite, which resulted in swelling and softening, obliteration of cellular structures, and increased reflectance once the bitumen solidified. The reflectance of altered (i.e., bitumen impregnated) alginite varies widely but is always intermediate between unaltered alginite and pore-filling solid bitumen in the same sample, apparently in proportion to the bitumen content. The average degree of bitumen impregnation is greatest in the Viburnum Trend, but the phenomenon remains significant within about 10 km east and west of the Trend. Solid bitumen observed at greater distances from the Viburnum Trend has not impregnated the associated alginite, nor has it preferentially accumulated near concentrations [of] kerogen. It was probably not generated within those rocks, considering the relative immaturity of the kerogen and the lack of a close physical association between the bitumen and kerogen. Thus the petrographic evidence indicates that the threshold of intense hydrocarbon generation has been reached only within about 10 km of the Viburnum Tend, thus defining an organic "thermal alteration zone." Elemental compositions are in agreement: samples from within about 10 km of the Viburnum Trend have lower O/C ratios and plot within the 'oil window' on a van Krevelen-type diagram.

This result implies that the Viburnum Trend host rocks were hotter than surrounding rocks at some time. The most likely cause of anomalous heating would be the warm (95-137°C) brines which deposited the Viburnum Trend ores, but there is no direct evidence regarding the relative timing of bitumen generation and ore deposition.

The mean reflectance of pure solid bitumen shows no evidence of the alteration zone: apparently it matured after the thermal anomaly had decayed. Mean solid bitumen reflectance, tentatively considered comparable to vitrinite reflectance, is in the range %Ro = 0.68 to 1.04, increasing with depth of burial, and increasing monotonically to the west across the Viburnum Trend.

Intra-sample variations in reflectance of both solid bitumen and bitumen-impregnated alginite are related to micron scale variations in the porosity of the rock matrix. This suggests that water washing (solution and/or oxidation) by pore fluids has contributed to the solidification and maturation of exposed bitumen. The distribution of such evidence indicates that water washing was a regional phenomenon not restricted to the Viburnum Trend.

In the immediate vicinity of the ore deposits organically generated pyrite occurs in some solid bitumen particles, indicating post-diagenetic activity of sulfate-reducing bacteria. Granular textured solid bitumen observed in some ore deposit and "Whiterock" samples may also be a result of microbial activity. (Author's abstract)

HENRY, D.J., 1988, Cl-rich minerals in high grade ironstones from the Beartooth Mtns., Montana: Implications for granulite facies fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A161. Also in J. Geol. Soc. India, v. 31, no. 1, p. 43-44, and Lunar Plan. Inst. Tech. Rept. 88-06, p. 67-69. Author at Dept. Geol. & Geophys., Louisiana State Univ., Baton Rouge, LA 70803-4101.

Although Cl-rich minerals have been recognized to develop in several petrologic environments (e.g., submarine hydrothermal vents, mylonites, skarns and late mafic pegmatite dikes in layered magmatic intrusions), they are most commonly found in granulite facies rocks. Three factors that favor Cl incorporation into hydrous minerals are an increase in the (1) $a(Cl^-)$ or $f(HCl)$ in the metamorphic fluids, (2) T and (3) size of the anion (OH^-) site (especially due to increasing Fe^{2+} contents). Clearly, before fully understanding granulite facies metamorphism the role of Cl in the metamorphic fluid must be explored in light of these factors.

The 3.4 Ga granulite facies ironstones of the Beartooth Mtns., Montana, having equilibrated at 700°C, at 5 kbar and under f(O_2) conditions near NNO, most commonly contain the assemblage: qtz + mag + opx + grt + cpx. There are also trace or minor amounts of a blue-green amphibole and dark brown biotite that are found as both inclusion and matrix phases. Both phases have some of the highest Cl levels that have been documented to date. The biotites, containing up to 2.9 wt % Cl (22% of the OH^- site), are also typically rich in Ti and Ba. The amphiboles, containing up to 2.8 wt % Cl (40% of the OH^- site), range in composition from a ferroan pargasite to a Cl-rich potassium hastingsite. In general accordance with expected crystallochemical controls, there is a general positive correlation among Cl levels and Fe^{+2}, Ba, K (in amphibole) and Al_{iv} (in amphibole). However, not all of the Cl variations can be strictly attributed to crystallochemical constraints. Based on the Cl contents of biotite, the relative f(HCl)/f(H_2O) ratios range from 0.05 to 0.4 suggesting locally variable fluid compositions. The relatively high f(HCl) necessary to stablize the Cl-rich minerals observed in the ironstones can only be attained in a coexisting aqueous phase. However, based on calculations and observed FI, the dominant fluid was CO_2. Consequently, it is probable that two fluid phases were present: a highly saline aqueous fluid and CO_2 fluid.

The presence of two fluid phases in granulites has several implications that influence the development of granulites. (1) Progressive Cl-enrichment in the aqueous fluid phases and coexisting minerals can result from an influx of CO_2 or loss of H_2O. (2) Brine and CO_2 fluid phases have contrasting physical properties and will move differentially in the granulites. (3) Saline aqueous fluids may act as effective transport agents for REE, Pb and Pt-group elements in granulites. (Author's abstract)

HERRERO, J.M., PEREZ-ALVAREZ, M., TOURAY, J.C. and VELASCO, F., 1988, Late thermal events in the Mesozoic Basque basin: Evidence for secondary fluid inclusions in Mississippi-Valley type fluorite occurrences: Bull. Minéral., v. 111, p. 413-420.

This is the full paper for abstract in Fluid Inclusion Research, v. 20, 1987, p. 167. (E.R.)

HERSHEY, J.P., PLESE, Tinka and MILLERO, F.J., 1988, The pK_I^* for the dissociation of H_2S in various ionic media: Geochimica Cosmo. Acta, v. 52, p. 2047-2051.

HERUT, B., STARINSKY, A., KATZ, A., BEIN, A. and GARFUNKEL, Z., 1988, Subsurface brine formation by sea water freezing (abst.): Chem. Geol., v. 70, p. 196. Authors at Dept. Geol., The Hebrew Univ., Jerusalem, Israel.

Sea water freezing is proposed as an important process in the formation of subsurface brines.

New, as well as available experimental data show, that both freezing and evaporation of sea water, followed by sulphate reduction, dolomite formation or chloritization, result in the well known characteristics of most subsurface brines, i.e.: high salinity, low (<0.86) Na/Cl ratio, low Mg/Ca ratio, low sulphate content, and a Ca//(SO_4 + HCO)>1 ratio. Hence, these properties in themselves, cannot be used as distinguishing criteria between the two processes.

However, the freezing and evaporation paths of sea water are clearly resolvable from each other in an Na/Cl-Br/Cl coordinate system, which is offered as a new tool for that purpose. This is displayed by comparing data of evaporative subsurface brines from the Dead Sea Rift and from Mississippi, with brines of a yet unclear origin from the Canadian Shield.

It is shown that the Canadian brines may well represent end products of a large-scale event of sea water freezing some time after the onset of the Pliocene glaciations. (Authors' abstract)

HERVIG, R.L., SMITH, J.V., and RIVERS, M.L., 1988, Fluorine content of upper-mantle minerals (abst.): EOS, v.69, p.502.

HEUSSER, E., KIRSTEN, T., RICHTER, H. and OEHM, J., 1988, Mass spectrometric analysis of noble gas isotopes: Max-Planck-Inst. für Kernphysik Heidelberg, Jahresbericht 1988, p. 155-156 (in German; English abstract).

Analysis of all stable noble gas isotopes in KTB core rocks provides a good opportunity to characterize the geochemical reservoir "continental crust" and to study mixing and transport processes between the various earth reservoirs. (Authors' abstract)

HEUSSER, E., KIRSTEN, T., ROCHOLL, A. and RICHTER, H., 1988, Noble gas isotopes in Hawaiian xenoliths (abst.): Chem. Geol., v. 70, p. 37. Authors at Max-Planck Inst. für Kernphysik, Postfach 103980, 6900 Heidelberg 1, Germany.

15 upper mantle derived ultramafic xenoliths from Salt Lake Crater, Oahu, Hawaii, consisting of 3 spinel lherzolites, 10 garnet-pyroxenites, 1 gabbro and 1 spinel olivine clinopyroxenite, have been analyzed for all noble gas isotopes. Extraction of the gases occurred by melting at a T of 1500°C. After purification the rare gases were separated by adsorption on a cryo-cooled charcoal trap and measured in two statically operating magnet spectrometer[s].

Concentrations of Ne, Ar and Kr are about two orders of magnitude below the atmospheric value which is given by the amount in the atmosphere divided by the total mass of the earth. Elemental abundance patterns are similar to the planetary pattern of ordinary CII chondrites. He concentrations are lower than in MORB glasses ranging from $5 \times 10^{-9} - 1 \times 10^{-6}$ cc STP/g. With one important exception all samples showed isotopic signatures which are typical for tholeiitic MOR basalts, i.e., $^3He/^4He = 8\text{-}10 \times R/R_{atm}$ and $^{40}Ar/^{36}Ar = 10^3 \times 10^4$. One spinel lherzolite showed indications for a higher contribution of primitive mantle gases, resulting in a high $^3He/^4He$-ratio of $40 \times R/R_{atm}$ and a low $^{40}Ar/^{36}Ar$-ratio of 340. (Authors' abstract)

HICKMAN, S., and EVANS, B., 1988, Experimental pressure solution in halite bicrystals (abst.): EOS, v.69, p.481. First author at Dept. of Earth, Atmos. & Planet. Sci., M.I.T., Cambridge, MA. 02139.

To understand the physical mechanisms contributing to the densification of non-hydrostatically loaded polycrystalline aggregates we have initiated pressure solution experiments in the halite/brine system. Two NaCl crystals polished to known curvatures (one flat, the other convex) are pressed together in saturated brine using small springs in a heated microscope stage. The geometry and size of the contact between these two crystals and their convergence with time is continuously monitored using reflected sodium interferometry and transmitted light photomicrography at temperatures of 5^0 to 95^0 C and loads of up to 5 Newtons. Special techniques are required in sample preparation, as the use of standard abrasive polishing methods results in an approximately $100\mu m$ deep surface damage layer which inhibits growth of the contact spot. Using a combination of solution polishing, fine mechanical polishing, and high temperature annealing, halite lenses used in this study are prepared to have very low surface dislocation densities and yield contact spot growth rates comparable to those obtained using unpolished NaCl cleavage fragments. Contacts fabricated "laboratory dry" and then immersed in brine at 50°C show an initial elastic/perfectly plastic contact spot corresponding to a mean normal stress of about 10 MPa, and grow with time at velocities that decrease approximately exponentially with fluid layer thickness. No undercutting is observed and residual fluid inclusions formed along the grain boundary indicate non-zero fluid wetting angles. The convergence rate across these initially dry boundaries is quite low: less than about 0.15 μm/day. Further experiments will measure the effect of temperature, normal stress, and grain boundary fabrication technique on convergence rates. (Authors' abstract)

HILTON, D.R., JENDEN, P.D., JEFFREY, A.W.A., KAPLAN, I. and CRAIG, H., 1988, Helium isotopes in continental natural gases: Results from Siljan, the Hugoton Panhandle and Appalachian Basin (abst.): Chem. Geol., v. 70, p. 202. Authors at Isotope Lab., Scripps Inst. Oceanography, La Jolla, CA 92093, USA.

Continuing investigations of the helium isotope systematics of continental natural gases now include analyses of 34 Siljan, 41 Hugoton Panhandle and 15 Appalachian Basin samples. Gases from the Siljan Ring structure in Sweden were extracted from circulating drilling fluids from the main hole (depth 6100 m), and a branching 'side-track' hole (4725-6220 m), drilled into Precambrian granite. Nearby gas seeps were also analyzed for ^{3}He/^{4}He. Gases from the drill holes are predominantly atmospheric with low [He] and [CH_4]. In contrast, both Hugoton Panhandle and Appalachian Basin gases contain significant [CH_4], and [He] is high, from 0.025-1.4%, and 0.023-0.215% respectively. The Hugoton Panhandle gases sample Permian age reservoirs and are from Kansas (15), Oklahoma (9) and Texas (17). The Appalachian gases sample lower Palaeozoic age reservoirs and are confined to New York State.

The ^{3}He/^{4}He ratios (R) of the Siljan samples range from 0.02 to 0.89 times the atmospheric value (R_a). Although some samples fall along a mixing trajectory defined by $R/R_a = 0.21$ and appear to be contaminated by 'cylinder helium' used at the well-head, for the most part this range can be explained by severe air dilution of radiogenic helium ($R/R_a = 0.02$) produced in situ in the granite. Local gas seeps away from the ring structure also show $R/R_a = 0.02$. A small number of samples scatter away from the mixing trajectories and have enhanced (He/Ne) ratios for their measured ^{3}He/^{4}He values. These have the lowest [He] (6-19 ppm) so that fractionation effects during degassing may have perturbed concentration ratios.

R/R_a ratios for the Hugoton Panhandle range from 0.04-0.27 with the highest value occurring in the Guymon field of Oklahoma. Unless the lithology of this region is characterized by an unusually high lithium abundance, or tritiogenic helium-3 has reached significant depths in the area, the range of R/R_a reflects a small but not insignificant input of mantle-derived helium. In contrast, R/R_a ratios for the Appalachian Basin cluster around 0.02, and are consistent with predicted ratios generated by radiogenic decay in average crust. (Authors' abstract)

HITZMAN, M.V., RECIO, C., CAULFIELD, J.B.D., BOYCE, A.J. and FALLICK, A.E., 1988, Stable isotopic (S, C, O) study of the Abbeytown Zn + Pb + Ag mine, Co. Sligo, Ireland (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. A38. First author at Chevron Mineral Corp. of Ireland, c/o CSA, the Triangle, Ranelagh, Dublin 6, Ireland.

^{34}S/^{32}S isotope ratios of diagenetic pyrite distal from the mine range from δ^{34}S -20‰ to -12‰. Main stage sulfides range from δ^{34}S -15‰ to -1‰ (median -11‰), and late pyrite from +11‰ to +16‰ (median +13‰). Unmineralized limestones average δ^{13}C +4.2‰ and δ^{18}O +25.5‰ (SMOW). Ore stage and post-ore calcites and dolomites show a depletion in ^{13}C and ^{18}O. These data are compared with other Irish deposits (of postulated SEDEX origin) and linked with fluid inclusion and structural studies to produce a contrasting genetic model. (From the authors' abstract by H.E.B.)

HO, S.E., 1987, Fluid inclusions: Their potential as an exploration tool for Archaean gold deposits: Univ. Western Australia, Geol. Dept., Publ. No. 11, p. 239-263. Author at Dept. Geol., Univ. Western Australia, Nedlands 6009, Australia.

Fluid inclusions in vein quartz from Western Australian Archaean Au deposits showing a variety of mineralization styles indicate that Au deposition was from distinctive, low salinity (typically <2 wt % NaCl eq.), H_2O-CO_2-rich (12-25 mole % CO_2) ore fluids with moderate densities (about 0.9 g cm^{-3}). Deposition occurred over a range of 200° to 400°C, but typically between 250° and 350°C. Sporadic phase separation in some deposits is characterized by variable phase ratios in apparently contemporaneous CO_2-rich inclusions. A lower P and/or T phase separation into CO_2- and H_2O-rich fluids was intermittent or late in the mineralization history of some deposits. Fluid inclusion and thermodynamic data indicate that the ore fluids were near-neutral to slightly alkaline, and were reducing. The presence of CH_4 is characteristic of, and restricted to, fluid inclusions in veins adjacent or in proximity to carbonaceous metasedimentary rocks, indicating that it is a fluid-wallrock reaction product rather than a P fluid component.

The low salinity and CO_2-rich nature of the ore fluid appear to be characteristic for Archaean Au deposits, and also for younger Au-only deposits. Hence, there is the possibility of using fluid inclusions in vein quartz to evaluate the likelihood of mineralization in a vein system, particularly in some weathered environments. Although visual examination is possible, decrepitometry has the greatest potential as a rapid guide to mineralized systems. However, more data on the nature of barren vein-systems are required. Where mineralization is already confirmed, CH_4 may be an important indicator of the presence of small, high-grade pods of Au ± tellurides associated with carbonaceous sediments. (Author's abstract)

HOCHELLA, M., TINGLE, T., BECKER, C., and MULHOTRA, R., 1988, Origin of complex hydrocarbons in samples of the Earth's mantle (abst.): EOS, v.69, p.502.

HOEFS, Jochen, 1987, Stable isotope geochemistry: Springer-Verlag, Berlin, 241 pp.

HOFFMANN, C.F., HENLEY, R.W., HIGGINS, N.C., SOLOMON, M. and SUMMONS, R.E., 1988, Biogenic hydrocarbons in fluid inclusions from the Aberfoyle tin-tungsten deposit, Tasmania, Australia: Chem. Geol., v. 70, p. 287-299. Authors at Bureau Min. Resources, Geol. & Geophy., Canberra, A.C.T. 2601, Australia.

Trace components in fluid inclusions from the Aberfoyle Sn-W deposit in Tasmania, Australia, were examined by thermal decrepitation-mass spectrometry. The technique involves the decrepitation of fluid inclusions by stepwise heating in the source of a mass spectrometer. In addition to water, other species identified were carbon dioxide and hydrocarbons. Detailed analysis of these hydrocarbons showed that they ranged in carbon number from C_1 up to at least C_{33} and probably comprised, in part, biological marker compounds, previously unreported in such high-T environments. Their presence suggests that the fluid responsible for mineralization was not entirely magmatic but contained a non-magmatic component evolved through fluid-rock interaction in the sedimentary country rocks. (Authors' abstract)

HOFSTRA, A.H., LANDIS, G.P., RYE, R.O, BIRAK, D.J., DAHL, A.R., DALY, W.E. and JONES, M.B., 1988, Geology and origin of the Jerritt Canyon sediment-hosted disseminated gold deposits, Nevada (extended abst.): U.S. Geol. Survey Circular 1035, p. 30-32.

See next item. (E.R.)

HOFSTRA, A.H., NORTHROP, H.R., RYE, R.O., LANDIS, G.P. and BIRAK, D.J., 1988, Origin of sediment-hosted disseminated gold deposits by fluid mixing - Evidence from jasperoids in the Jerritt Canyon gold district, Nevada, U.S.A. (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 284-289. First author at U.S. Geol. Survey, Box 25046, Denver, CO 80225.

Fluid inclusions in Au stage jasperoid and barite were studied by microthermometry, mass spectrometry, and laser Raman spectroscopy. They have a wide range of salinities (<0.1 to 15 eq. wt. % NaCl) and gas contents (<0.5 to 12 mole %). At one extreme are saline brines (~3-10 eq. wt. % NaCl) with ~5 mole % gas. CO_2 is the dominant gas (~4 mole %) with up to 1 mole % of CH_4 and N_2 and typically <0.1 mole % of short chain hydrocarbons, H_2S, SO_2, and Ar. However, some inclusions contain up to 1.0 mole % H_2S. At the other extreme are very low salinity (<0.1 eq. wt. % NaCl), low gas (<0.5 mole %) fluids with similar gas speciation. CO_2/CH_4 ratios are typically near 100 but range from 5 to 500. Minimum trapping conditions for the saline, gas-rich inclusions were 200-250°C and 0.5 to 1.0 kbars. Fluid inclusion evidence of boiling or fluid immiscibility has not been observed in these samples. These data suggest that two fluids were present during mineralization and that mineralization took place at a depth of at least 1 km and possibly as deep as 5 kms. The saline, gas-rich fluid containing 0.1 to 1.0 mole % H_2S and 3 to 10 eq. wt. % NaCl was capable of transporting large amounts of Au as bisulfide complex and that chloride complexes were less important. It also shows that oxidation is a particularly effective Au precipitation mechanism. (From the authors' abstract)

HOLDEN, D.J., 1987, Mineralization styles of the Carrick gold field, central Otago (abst.): Geol. Soc. N. Zealand Misc. Pub. 37A, Programme and Abstracts 1987 Conf. Geol. Soc. N. Zealand (unpaginated). Author at Dept. Geol, Univ. Otago, Box 56, Dunedin.

The lodes of the Carrick range Au field may be classified into three broad categories: crushed shear zone material, coarse "vuggy" quartz breccia and fine-grained silicic schist breccia.

Coarse quartz breccia observed immediately west of the main lode development exhibits open-spaced filling textures with millimeter size quartz needles and is strongly indicative of shallow formation. Schist fragments within the breccia are bleached and altered.

The intensely brecciated silicified schist is observed about the lower Carrick lodes with an approximate east/west strike and near vertical dip. These breccias, or cataclasites, are barren and show no sign of reactivation.

Fluid inclusion data to date shows similar Th for both the coarse quartz and the "mullock" material ranging from 155°C to 195°C and an Tm ice ranging from -2.6°C to -3.0°C. Both lode types appear to have been derived from similar fluids. No fluid inclusion data are yet available for the silicified schist breccias. (From the author's abstract by E.R.)

HOLLAND, H.D., DAS, N. and WEINBERG, A., 1988, The evolution of seawater during the Phanerozoic (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 49. Authors at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138, USA. Continued next page.

The composition of inclusion fluids in halite from marine evaporites can be used to define the chemical evolution of seawater since late Proterozoic time. We have developed a technique for extracting fluid from single fluid inclusions > 250 µm in diameter, and for analyzing the inclusion fluids for all of their major and a few of their minor constituents. The composition of inclusion fluids in Messinian salt from the Red Sea falls along the evaporation path of modern seawater, but K^+ and Br^- appear to have been added to the inclusion fluids during the migration of these fluids through the host salt.

Inclusion fluids in the Salado Formation indicate that the composition of Permian seawater was very similar to that of modern seawater, but that its K^+ content may have been twice as great. Inclusion fluids in halite from the Devonian Prairie evaporites in Saskatchewan and from the Silurian Salina formation in Michigan indicate that the composition of seawater during both periods was close to that of modern seawater. The reasons for the apparent near-constancy of the composition of seawater during much of the Phanerozic are presently not understood. (Authors' abstract)

HOLLISTER, L.S., 1988a On the origin of CO_2-rich fluid inculsions in migmatites: J. Metamorphic Geol., v. 6, p. 467-474. Author at Dept. Geol. & Geophy. Sci., Princeton Univ., Princeton, NJ 08544, USA.

Nearly pure CO_2 fluid inclusions are abundant in migmatites although H_2O-rich fluids are predicted from the phase equilibria. Processes which may play a role in this observation include (1) the effects of decompression on melt, (2) generation of a CO_2-bearing volatile phase by the reaction graphite + quartz + biotite + plagioclase = melt + orthopyroxene + CO_2-rich vapor, (3) selective leakage of H_2O from CO_2 + H_2O inclusions when the P in the inclusion exceeds the confining P during decompression, and (4) enrichment of grain-boundary vapor in CO_2 by subsolidus retrograde hydration reactions. (Author's abstract)

HOLLISTER, L.S., 1988b CO_2-rich fluid inclusions in greenschists, migmatites, granulites, and hydrated granulites (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 46-47 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 70-71). Author at Dept. Geol. & Geophys. Sci., Princeton Univ., Princeton, NJ 08544.

[From a review of various papers], it appears, therefore, that we have some way to go before we can confidently relate, in all cases, entrapment of fluid inclusions to peak metamorphic conditions. This is not to say that fluid inclusion research in metamorphic rocks should not be pursued vigorously. Crawford and Hollister (1986) review cases where fluid inclusions have been shown to be related to peak metamorphic conditions, and Olsen (1987) related fluid inclusions to conditions during anatexis. And a very productive use of studies of fluid inclusions in metamorphic rocks has been constraining the post metamorphic exhumation histories of metamorphic terranes. (From the author's abstract; E.R.)

HOLM, D.K., CRAW, J. and NORRIS, R.J., 1987, Brittle-ductile transition displayed by schists uplifted adjacent to the Alpine Fault, Franz Josepf, Westland (abst.): Geol. Soc. N. Zealand Misc. Pub. 37A, Programme and Abstracts 1987 Conf. Geol. Soc. N. Zealand (unpaginated). First author at Dept. Earth & Planet. Sci., Harvard Univ., Massachusetts, USA.

Brittle-ductile transitional structures comprise arrays of ductile extensional shear zones, extension veins and internal boudinage features, which overprint ductile buckling and boudinage of arrays of quartz veins cross-cutting the dominant foliation. Fluid inclusions have been examined from quartz crystals in subhorizontal extension fractures formed during the late brittle phase, in extension fractures related to internal boudinage structures formed during the brittle-ductile phase, and from the deformed veins. P-T estimates of ~700 bars at 280°C for the brittle phase and 1.5 kbars at 350°C for the brittle-ductile transition were obtained. The deformed veins show evidence of extensive fluid infiltration during the later phases - probable P inclusions give an isochore from which an estimate of ~5 kbars at 450°C is suggested for their deformation. Well-developed biotite selvedges attest to the deformation taking place within the biotite stability field. The P-T-time path indicated by the data represents very rapid uplift from depths of 15-20 km. (From the authors' abstract by E.R.)

HOLMGREN D., CARMEN, 1985, Basis for a genetic model of the El Soldado deposit, Region V, Chile: Abstracts, IV Congreso Geol. Chileno, 1985, p. 114 (in Spanish; translated by Gary Landis).

The El Soldado copper deposit is situated in the Cordillera de la Costa, Region V. Its geographic coordinates are 32°38'8"S latitude and 71°6'9"W longitude. The mineralized bodies are emplaced in volcanic rocks with intercalated sedimentary rocks belonging to the Lo Prado Formation, of Neocomian age, and exhibit a strong structural and lithological control. The ore is P, is deposited in zoned manner, and is composed of limited pyrite and abundant chalcopyrite and bornite, with subordinate chalcocite and covellite.

Sulfur isotope studies of the distinct zones of ore body mineralization show a range in $\delta^{34}S$ near zero permil. These values contrast with the range for the low levels of framboidal pyrite and syngenetic pyrite in the sediments, which are as high as +28.4 permil.

Analysis of fluid inclusions in quartz and calcite show mineralizing fluids that are of very high salinity or saturated. The highest Th determined (>257°C), uncorrected for P, corresponds to the chalcopyrite-pyrite assemblage. The bornite-chalcocite zone indicates a 200°-220° range (uncorrected), and the late veinlets of barren (unproductive) calcite indicate T >150°C.

The preferred mechanism for ore precipitation is by reaction of mineralizing fluids with the enclosing rocks,and secondarily by drop in T and/or P. There is no evidence of boiling.

This study is complimented by [examination of] various samples of the strata-bound deposits Veta del Agua (near El Soldado) and the Resguardo mine (district of Punta del Cobre, Region III), the results of which are very similar to those obtained for El Soldado.

Considering the geology of the deposit, its hydrothermal alteration, and antecedents [precursors] that were mentioned, a magmatic origin is postulated for the mineralization, related to a declining stage of acid volcanism activity in the sector. Alternate genetic models are discussed. (Author's abstract)

HOLTZ, F., EBADI, A., BARBEY, P., JOHANNES, W. and PICHAVANT, M., 1988, Phase relations in the Qz-Ab-Or system at 2 and 5 kbar: The effect of a(H_2O) (abst.): Terra cognita, v. 8, p. 66. First author at Inst. für Kristallogr. & Petrogr., Univ. Hannover, D-3000 Hannover-1, FRG.

Solidus and liquidus phase relations have been determined in the Qz-Ab-Or at 2 and 5 kbar under various a(H_2O). The results allow the isobaric effect of a(H_2O) on phase relations to be specified. Microthermometric studies of the fluid inclusions trapped in glass reveal that the fluid phase composition does not depart significantly from the H_2O-CO_2 binary. Compared to H_2O-saturated conditions, the minimum liquidus composition shifts towards the Qz-Or binary at approximately constant normative Qz contents. This last result implies a preferential association of H_2O with the albite-forming components in the melt, in contrast with existing calculations (Nekvasil and Burnham 1987). (From the authors' abstract)

HORVATH, H.S., 1988, The geology and genesis of the Eldorado Au-bearing lode, Tennant Creek, N.T., Australia: BSc thesis, Univ. Tasmania.

The Eldorado deposit is one of a unique group of magnetite- and hematite-rich bodies which hosts Au, Bi, and Cu mineralization in the Tennant Creek Goldfield. These bodies were formed by hydrothermal sediment-replacement processes, and are stratigraphically confined to structural traps in the turbidite sedimentary rocks of the Carraman Formation of the Lower Proterozoic Warramunga Group.

The Eldorado lode is located in a second-order anticlinal feature (Ivanac, 1954) along a prominent E-W striking line of lode called the "Juno Line." The lode has a slightly flattened pipe shape parallel to the regional ~E-W axial plane cleavage. It measures ~85 x 65 m near the surface and tapers with depth. The lode pitches ~ENE dipping 65°, and strikes down-dip 260 m. The uppermost 60% of the lode has been displaced ~170 m WSW by a reverse thrust fault (Turner Fault).

The lode is composed of two main zones: (i): an essentially barren Massive Magnetite Hematite, containing magnetite, hematite, ± quartz ± chlorite ± trace W, and (ii): a Breccia Stringer zone located at the footwall of the Massive Magnetite Hematite, composed of chloritized sedimentary fragments, magnetite, hematite, quartz, various chlorite varieties, ± traces of Au, Bi, Cu, W, and enriched in REE.

This investigation examined the controls on economic mineralization in these two zones by analyzing: mineral texture, trace and rare earth elements, fluid inclusions contained within quartz, chlorite minerals, and oxygen isotopes using quartz-chlorite mineral pairs. It has been found that two P mineralizing stages formed the two zones. The Massive Magnetite Hematite was formed by fluids with a modal T ~220°C, and salinities ~17 eq. wt.% NaCl. In contrast, the Breccia Stringer zone contained fluids marked by generally higher T and salinities. Fluids in paragenetic association with Au and Bi indicate modal T of 300°C, salinities between 37 and 42 eq. wt.% NaCl, and log fO_2 ~-33 units.

Dating by Black (1984) indicates that the Tennant Creek mineralization occurred ~1810 million years ago and concurrently with the intrusion of the Tennant Creek Granite, which suggests that the granitic magmas provided the heat source for the hydrothermal entrainment of the deep sedimentary brines which led to mineralization. The second stage of mineralization may have been caused by 'pulses' of magmatic fluid entering the system, and thus providing the added T and salinity to transport the economic metals.

At some unknown time after hydrothermal mineralization, the Eldorado lode suffered faulting/fracturing which allowed the entry of oxidizing meteoric groundwaters. These waters remobilized and redeposited some economic mineralization above the water table by supergene enrichment.

It is proposed that for a Tennant Creek lode to contain economic mineralization then, high T (300°C+), high salinities (>40 eq. wt.% NaCl) [implying low pH ~3-4], and high fO_2 are required by the hydrothermal fluids to leach and transport economic metals. In these conditions Au and Bi are transported as chloride complexes (Huston & Large, 1987). (Author's abstract)

HOY, L.D., KHEANG, L., and TRUDEL, P., 1988. Evidence from fluid inclusion and stable isotope studies for the thermochemical nature of fluids responsible for Au mineralization in Bousquet township, Quebec (abst.): GAC/MAC Program with Abstracts, v.13, p.A58. Authors at Mineral Expl. Res. Inst., C.P. 6079, Succursale "A", Montréal, P.Q., H3C 3A7.

Au mineralization in the Bousquet Township is found within a roughly east-west trending zone of strongly deformed and sheared metavolcanics of the upper Black River Group. Typically this mineralization is found in or in close spatial association to east-west trending, steeply dipping quartz (±pyrite ±ankerite) veins situated within the zone of deformation. The results of a regional examination of the stable isotopic compositions of vein minerals and their fluid inclusion thermochemistry is reported here. Samples associated with Au mineralization were obtained from zones of present production (e.g., Doyon, Bousquet mines), past producers, and mineralized prospects. Nonmineralized samples were obtained from within these mineralized zones and from footwall and hangingwall rocks in the district.

Results of fluid inclusion studies indicate T and compositional differences between Au-veins and sterile veins. All veins are dominated by CO_2 and/or CO_2-H_2O inclusions; methane is often detected in mineralized veins. Measurements indicate a gradient in vein formation T. Highest T_h are measured in mineralized veins (250-350°C), those from sterile (ore zone) veins are slightly lower (200-300°C), and FW and HW barren veins are lower (100-200°C). Similar trends are indicated by preliminary O isotope data. Salinities of formation fluids also differ between Au-bearing and sterile veins. Au-veins contain fluids of low salinity (2-5 wt.% NaCl eq.). Compositionally, the fluids are similar, high in Na, Ca, and S and low in Cl and K. These isotopic and fluid inclusion data may provide a useful exploration tool.

Three possible interpretations are consistent with the data: (1) all veins formed from the same hydrologic event, Au deposition occurred in high T centers of the system, (2) barren veins formed from evolved fluids responsible for mineralization at depth, or (3) fluids responsible for sterile veins are temporally unrelated to Au mineralization and never attained the proper thermochemical conditions necessary for mineralization. (Authors' abstract)

HUA, Yongfeng, 1988, Preliminary study on the origin and mineralization feature of mercury and gold deposits in Guizhou Province East part (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 219-223.

It is concluded that the Hg-Au deposits might be of sedimentary origin. Studies of the fluid inclusions and some geological conditions of the deposits suggest that the Hg-Au mineralization has undergone a late, low-T hydrothermal solution stage probably in the nature of heated confined groundwater action. (From the author's abstract)

HUANG, Dianhao, WU, Chengyu and NIE, Fengjun, 1988, Geological features and genesis of the Jinduicheng porphyry molybdenum deposit, Shaanxi Province, China: Geochemistry (Chinese), v. 7, p. 136-147. Authors at Inst. Min. Deposits, Chinese Acad. Geol. Sci., PRC.

Situated in the Henan-Shaanxi fault-uplift area on the southern margin of the Sino-Korean Paraplatform, the Jinduicheng porphyry molybdenum deposit is the most important molybdenum producer in China. During Yenshanian the Jinduicheng granite porphyry was emplaced in metaspilite of the Proterozoic Xionger Group, controlled by a NW-trending fault. Mineral compositions are mainly quartz (25-40%), microcline and microcline-perthite (27-40%) and plagioclase (An8-14, 14-32%), associated with minor biotite and muscovite, and phenocrysts are made up of K-feldspar, quartz and plagioclase. Accessory minerals include magmatite[sic], apatite and zircon. The porphyry contains SiO_2 73.83% and $K_2O + Na_2O$ 8.06% (with K_2O/Na_2O ratio being 1.82), belonging to the calc-alkaline series.

Mineralization occurs in the porphyry body and biotitized and hornfelsized spilite within the exocontact zone. The maximum depth of mineralization reaches 1000 m below the surface. According to mineral assemblage, ore veins are classified into five types: (1) pyrite-quartz; (2) pyrite-K-feldspar-quartz; (3) pyrite-molybdenite-quartz. (4) pyrite-molybdenite-K-feldspar-quartz; and (5) muscovite-fluorite-pyrite-molybdenite-quartz. As the most important economic molybdenum mineral, molybdenite occurs in various forms. Wall-rock alterations show a gross zonation of K-feldspathization-greisenization → silicification → propylitization from the porphyry outwards, of which silicification is most intense and has close genetic relationship with Mo mineralization.

Fluid inclusion studies yield Th that range from 250 to 240°C, with the main stage between 400 and 300°C. Gas inclusions frequently coexist with multiphase inclusions containing such dms as halite, sylvite, molybdenite and K-feldspar. Under moderate-high T, lower fO_2, high fS_2 and weak acidity conditions, boiling of ore-forming fluids is a prerequisite for the precipitation of molybdenite. Sulfur, oxygen and carbon isotopic compositions suggest that the high T stage (450°C), magmatic water is dominant and at the main ore-forming stage a mixture of magmatic water and meteoric water is expected. At the late stage, the mixture is predominated by meteoric water. Sulfur and molybdenum are mostly of magmatic origin. (Authors' abstract)

HUBERT, P., BENY, C., OUSTRIERE, P. and TOURAY, J.C., 1988, Evolution of fluids associated with Au-bearing mineralizations from the vein field of Sanoukou (Kenieba district, Mali), in Metal ore deposits in their geological context, eds., Z. Johan and D. Ohnenstetter: BRGM document 158, Vol. II, p. 667-694

From a textural and paragenetic study of the quartz veins, one may establish in the Sanoukou Au prospect the following sequence: 1) early formation of milky quartz, often in association with albite; 2) genesis, after deformation and recrystallization processes of "micro-saccharoidal" quartz, associated with muscovite-chlorite-ferroan dolomite, then sericite-arsenopyrite and finally pyrite. Native Au forms at this stage; and 3) late crystallization in geodes and healed fractures of clear "hyaline quartz" with trace amounts of galena, chalcopyrite and sulphosalts. At this stage, native Au has a significant Ag content.

Suitable fluid inclusions were located only within milky and hyaline quartz. From optical investigations, one may distinguish early CO_2-rich inclusions (type C) from late water-dominated ones (type L). From microcryoscopic and Raman microprobe data, the volatile phase within C inclusions is either nearly pure CO_2 or a mixture of the latter gas with methane and/or nitrogen. C inclusions homogenized either to the liquid or to the vapor phase in the 260-360°C range with a distinct peak around 300-320°C. Frequently, decrepitation occurred before homogenization. L inclusions display lower Th and may be classified within two groups according to their salinity.

Interpretation of the fluid inclusion data recognizes two successive main stages along the fluid recording at Sanoukou: 1) P drop within a lithostatic regime. With trapping CO_2-rich vapors at ~300-320°C, 1.8 kbar; following a P drop, other vapors (CO_2 about 80 mole %) injected into an aqueous CO_2-rich solution, leading to immiscible fluids. Then one had a sudden evolution at decreasing T, P and XCO_2. At this stage, pH and fO_2 variation probably played a part with respect to Au deposition; and 2) P-T decrease under a hydrostatic regime, with trapping of solutions of increasing salinity. At this stage, significant Au reconcentrations occurred. (Authors' abstract)

HUBERT, P., DEGRANGES, P. and RANKIN, A., 1988, Characterization of gold-bearing quartzes by destructive chemical analysis of fluid inclusions.

Application to the Sanoukou prospect (Kenieba district, Mali), in Metal ore deposits in their geological context, Z. Johan and D. Ohnenstetter, eds.: BRGM document 158, v. II, p. 695-713

The fluid inclusions from about twenty samples of quartz collected in the Au-bearing shear zone of Sanoukou (Mali) were analyzed by two complementary destructive methods: analysis of cations by decrepitation and ICP spectrometry; analysis of gases by decrepitation and gas chromatography with an original technique carried out at the BRGM. Na, K, Ca, Sr, Ba, Li, S, on one hand, CO_2, CH_4, C_2H_8 (C_3, C_4) on the other hand were determined.

Comparison of the results obtained by these two techniques allowed detection of a direct correlation between Li/Na and CO_2, and an inverse correlation between K/Na and CO_2. These correlations attest the connection of the Li and the early CO_2-rich fluids and the connection of the K and the later aqueous fluids. For these later ones, the Na-K and Na-K-Ca geothermometers were used and gave similar results (100°-190°C), in good agreement with the T determined by microthermometry for the late aqueous fluids.

At last, the comparison of the Au content of these samples with the chemistry of the trapped fluids showed that the Au-rich quartz (Au >1 ppm) presented high K/Na and low Li/Na ratios. These samples are characterized by a predominance of the late aqueous inclusions. Utilization of this result in prospecting can be considered. (Authors' abstract)

HUDSON, A.E. and ATKINSON, W.W., 1988, A geochemical analysis of the tungsten vein deposits in Boulder County, Colorado (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 421. Authors at Dept. Geol., Univ. Colorado, Boulder, CO 80309.

The Boulder County tungsten district is a narrow belt of shallow veins primarily within Precambrian quartz monzonite. Wolframite (Fe, Mn)WO_4, is believed to be genetically related to Early Tertiary biotite monzonite porphyry dikes and biotite latite intrusion breccia.

Early work by Lovering and Tweto suggested that vein mineralization resulted from a shift in solution chemistry from acid to alkaline conditions. In contrast, fluid inclusion determinations in the present study indicate that wolframite was deposited from boiling solutions below 200°C at a maximum depth of 200 m, suggesting that boiling may be a more important mechanism for ore deposition. Tm ice correspond to salinities of less than 8 wt % eq.

Mn/Fe ratios in wolframite increase from near zero in the central part to a maximum of 1.34 in the northern part of the district. These high ratios coincide with the occurrence of scheelite and an increase in sulfide mineralization. A large Ca peak was observed in some spectra of the Mn-rich wolframite. This could be attributed to submicroscopic scheelite inclusions, replacement of wolframite by scheelite, or by limited solid solution between huebnerite-ferberite and scheelite end members. A vertical zonation with Mn-poor wolframite in the deepest central portion of the district and progressively higher Mn/Fe ratios toward the flanks suggest a single deep centralized source for the mineralizing fluids. (Authors' abstract)

HÜGI, M., 1988, Petrography and mineralogy of the Lercheltini-zone (region) (Monte-Leone-nappe, Binn valley, VS). The quartz crystals from the mineral mine Lengenbach and their inclusions: Thesis, Univ. Bern, Switzerland, 131 pp. (in German; translation by H.A. Stalder).

In the second part of this paper, mainly quartz-crystals from the Lengenbach mine are treated. The Lengenbach mine is world famous for its hydrothermal mineralization in Triassic dolomite which is very rich in species, particularly the As-sulfosalts with the elements Pb, Tl, Ag and Cu, which are only known from this place.

The fluid inclusions in quartz have been studied mainly by microthermometry, and in part by Raman spectroscopy and electron microscopy. They can be classified in three types:

Type I: CO_2-rich inclusions: Directly related to the mineralization are inclusions (type Ia), that have - besides CO_2 and H_2O - also H_2S (up to 2 mol.%) and an As-sulfide as dm. Th (without dissolution of the dm) are 280° to 330°C. The As-sulfide consists generally of an As-sulfide glass (the probable composition is AsS_3), partly of orpiment (As_2S_3) and exceptionally of realgar (As_4S_4). These inclusions are of great importance for the interpretation of the mineral-formation, they show that As and S were parts of the mineral-forming solution. Type I inclusions without H_2S and As-sulfide (type Ib) occur in fissure quartz of nonmineralized dolomites at the Lengenbach and its surroundings.

Type II: salt-rich inclusions: The rare type II-inclusions, which have been found only at Lengenbach, contain relatively little CO_2, a saturated salt-solution with different precipitated salt crystals, among them always and above all NaCl. Th (without complete dissolution of NaCl) are 240° to 270°C. The formation of type II-inclusions took place probably by dissolution [i.e., immiscibility] of the hydrothermal fluid in a CO_2-rich (type I) and a salt-rich phase. Because of different viscosities the two phases divided and occupied different places in healing-fissures of quartz.

Type III: watery inclusions: The CO_2-inclusions diminished continuously during the growth of quartz. The two-phase type III-inclusions therefore represent the youngest formations; they have Th = 170° to 250°C.

Based on the existing data it can be concluded that Tt of the type I-inclusions, and thus also the mineral-forming hydrothermal phase, were ~400°C and 2 kb, whereas the type III-inclusions formed at ~250°C and 1 kb. Because of the uncertain basis of the data, the P-T conditions are only approximations.

HULEN, J.B. and NIELSON, D.L., 1988a Hydrothermal brecciation in the Jemez fault zone, Valles caldera, New Mexico: results from continental scientific drilling program core hole VC-1: J. of Geophy. Res., v.93, no.B6, p.6077-6089. Authors at Univ. of Utah Res. Inst., Salt Lake City, Utah.

These hydrothermal breccias were intensely altered, during at least five major stages, to quartz-illite-phengite-pyrite aggregates; traces of molybdenite occur locally. This assemblage indicates interaction with hydrothermal fluid > 200°C. The extrapolated present maximum T of 184°C in the breccia zone therefore represents considerable cooling since these phases were formed. Fluid inclusions in the breccias also preserve evidence of the prior passage of hotter fluids. The inclusions are principally two phase, liquid-rich, S in origin, and concentrated in hydrothermal quartz. Older high-salinity inclusions, unrelated to brecciation, have Th 189°-246°C. Younger inclusions, in part of interbreccia origin, are low-salinity and 230°-283°C; locally coexisting liquid- and vapor-rich inclusions document periodic boiling of the dilute fluids. These fluid inclusion data can be combined to model hydrothermal brecciation at the VC-1 site. Late quartz veining, hydrothermal alteration, and molybdenite mineralization were probably produced by the fluids responsible for brecciation. (From the authors' abstract)

See also Hulen, Nielson, Goff, Gardner and Charles in Fluid Inclusion Research, v. 20, 1987. (E.R.)

HULEN, J.B. and NIELSON, D.L., 1988b Hydrothermal brecciation in the

Jemez fault zone, Valles caldera, New Mexico (abst.): EOS, v.69, no.16, p.289. Authors at Univ. of Utah Res. Inst., Salt Lake City, Utah 84108.
See previous item.

HULSEBOSCH, T.P., FROST, B.R. and TOURET, J., 1988, Fluid and solid inclusions from pyroxene-bearing granitoids: Evidence for immiscible magmatic fluids (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A313. First author at Univ. of Wyoming, Dept. Geol. & Geophys., Box 3006, Laramie, WY 82071.

A systematic investigation of inclusions in monzosyenite from the Laramie Range, Wyoming, and in pyroxene granite from the Wind River Mountains, Wyoming, provides evidence for two different immiscible fluid systems in these rock types.

The Sybille Monzosyenite contains CO_2-rich fluid inclusions with an average density of .68 gm/cc. These inclusions represent magmatic fluids trapped at approximately 975°C and 3 kbar. Partially decrepitated fluid inclusions containing aqueous brines are also observed. Decrepitation of brine filled inclusions has produced abundant solid salt inclusions. The salts range from K-bearing halite to ternary Na-K-Cl chlorides. The latter is indicative of precipitation at T above 500°C. Some salt inclusions are intimately associated with inclusions of hornblende and hedenbergite indicating that the brine inclusions are primary. These relationships indicate that crystallization of the monzosyenite occurred in the presence of immiscible CO_2-rich and saline aqueous fluids.

Several types of inclusions are observed in the pyroxene granites. CO_2-rich fluid inclusions with an average density of .80 gm/cc represent a primary magmatic volatile phase that was trapped at approximately 800°C and 5 kbar. Saline aqueous fluid inclusions are also observed, however, they were trapped at much lower P-T conditions than the CO_2 inclusions. Solid inclusions of carbonate occur as isolated groups within the pyroxene granites. The mode of occurrence and morphology of these inclusions are similar to quenched carbonate liquids reported from experimental runs in granitic systems (Koster Van Groos and Wyllie, 1973). We feel that carbonate inclusions in the pyroxene granites represent an immiscible magmatic fluid. (Authors' abstract)

HURAI, Vratislav, 1988, P-V-T-X tables of water and 1-25 weight percent NaCl-H_2O solutions to 500°C and 5000 x 10^5 Pa: Acta Geol. & Geographica Univ. Comenianae (Bratislava), Geologica Nr. 44, p. 101-135. Author at Geol. Inst. of Comenius Univ., Mlynská dolina G, 842 15 Braislava, ČSSR.

The paper presents detailed tables of NaCl-H_2O system in isochoric-isoplethal projection, which is the most suitable form for fluid inclusion data interpretation. Summarized are PVT properties of vapor-saturated liquids from 83° to 325°C and P greater than the saturation vapor P on corresponding isochores to 500°C and 5000 x 10^5 Pa. (Author's abstract)

HUTCHINSON, C.S., ed., 1988, Geology of tin deposits in Asia and the Pacific: New York, Springer-Verlag, 688 pp.

IBARAKI, Kenzo and SUZUKI, Ryoichi, 1988, The Hishikari gold deposit: Kagoshima Int'l. Conf. on Volcanoes Proceedings, p. 759-762. Authors at Sumitomo Metal Mining Co., Ltd.

The deposit is of an epithermal Au-Ag bearing quartz-adularia vein type which generally strikes N 50° E, dipping steeply 70° to 90° to the north. It is composed of 4 major vein group and numerous veinlets in an area of 1,100 m by 200 m. They occur in both the Shimanto Supergroup and the Hishikari Lower Andesites. Vein width is usually from 1 m to 3 m (maximum 8 m) with strike length of 300 to 400 m. Known bonanza zones are located vertically between 130 m to -20 m a.s.l. The vein shows a rhythmic banding structure symmetric from both wallside in general. Gangue mineral are composed mainly of quartz, adularia and smectite, accompanied by a minor amount of carbonates (calcite, siderite, ankerite, rhodochrosite), truscottite, gypsum, alunite(?), wairakite and laumontite. The major constituent ore minerals are electrum, naumannite, chalcopyrite, pyrite and marcasite, while minor amounts of Ag-Au selenide, acanthite, sphalerite, galena, Cd-sulfide, stibnite and hematite are so far been identified.

Alteration zoning appears from the mineralized center in the following order: Chlorite - sericite/smectite → Sericite/smectite zone. These alteration envelopes are surrounded by smectite and halloysite zones.

Th of fluid inclusions in quartz range 164°C to 255°C. (From the authors' text)

IKORSKY, S.V., PRIPACHKIN, V.A. and FANYGIN, A.S., 1988, Microinclusion gases as a research-assessment feature of apatite mineralization in the Khibiny alkaline massif, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 217-222 (in Russian).

IMAI, Hideki, ADACHI, Masaho, TAKAHASHI, Mikio, YAMAGUCHI, Mitsuo and YASHIRO, Koji, 1988, Sulfide mineralization in Oku-Aizu geothermal field, with genetic relation to epithermal gold deposits: Mining Geol., v. 38, no. 3, p. 291-301 (in Japanese; English abstract). First author at Central Res. Lab., Mitsui Mining & Smelting Co., Ltd., Haraichi, Ageo City, Saitama 362, Japan.

Sulfide scales were collected from a test well of the Oku-Aizu geothermal field. Veinlets composed of similar sulfide minerals in the country rocks were also obtained from the drilled cores. Both were deposited from compressed geothermal hot water in this area. These minerals are listed in Table 1. The analyses of the geothermal water are shown in Table 4. From the analytical data, the pH of the geothermal fluid is calculated to be 4.47 at 250°C in the case of activity coefficient equals unity.

Two kinds of rock alteration are recognized in this area. One is caused by neutral to alkaline hot water. The other is due to the acid hot water. The minerals of both alterations are shown in Table 3. The rocks along fissures containing the present compressed geothermal fluid are subjected to neutral to alkaline alteration. From these facts, the relation log fO_2-pH-log fS_2 of the environment of the geothermal fluid is shown in Fig. 9. Acid alteration occurs sporadically in this area. The acid alteration would be referred to the vapor-dominated system, separated by boiling from the compressed hot geothermal fluid. It might condense to acid hot water during cooling.

In Japan, the epithermal Au deposits are classifed into two types. The one is Au (Ag)-quartz (adularia) vein, surrounded by rocks [having] suffered neutral to alkaline alteration; adularization, sericitization and/or chloritization. The other is massive silicified rock containing Au, which is surrounded by rocks subjected to acid alteration; kaolinization and alunitization. The both types of Au deposits might be attributed to the same phenomena as the two kinds of geothermal fluids stated above. (Authors' abstract)

IMBUS, S.W., ENGEL, M.H., ELMORE, R.D. and ZUMBERGE, J.E., 1988, Organic geochemical study of fluid inclusions in calcite speleothems: Implications for paleomagnetic dating of hydrocarbon migration (abst.): Geol. Soc. Am.

Abstr. with Programs, v. 20, no. 7, p. A259. First author at School Geol. & Geophys., The Univ. Oklahoma, Norman, OK 73019.

The dating of fluid migration events is of critical importance with respect to petroleum exploration efforts. With the exception of indirect structural and tectonic considerations, however, independent methods for constraining the timing of oil migration remain to be developed. We have recently reported that the migration of oils through carrier beds can result in precipitation of authigenic, magnetic minerals. Consequently, it was demonstrated (and independently confirmed by fossil evidence) that paleomagnetic methods could be used to determine the geologic age of karst origin (Elmore et al., 1987, Nature 325, 428). The speleothems are hosted in the Kindblade Formation (Ordovician) in southwestern Oklahoma. In the present study we attempt to evaluate the nature of the relationship of hydrocarbons to authigenic magnetite via a detailed organic geochemical and petrographic investigation of possible mechanisms of hydrocarbon entrapment in the speleothem crystals. Gas chromatographic analyses of the C_{15+} aliphatic fraction isolated from the speleothems indicates that biodegradation is slight, whereas oil found in the host limestone is extensively degraded. Microscopic analyses and the results of pyrolysis experiments (thermal decrepitation) reveals more than one mode of occurrence of hydrocarbon inclusions in the speleothem crystals. Techniques devised to isolate hydrocarbons from the various types of inclusions elucidate the extent to which a redistribution of compounds occurred as the calcite precipitated out of solution in the presence of migrating oil. Analysis by GC and GC/MS is used to establish the relationship between the speleothem oil and tentative families of oils delineated in Oklahoma. Finally, having constrained the time of migration for this speleothem oil and tentatively established a source, we may begin to assess a possible migration pathway. (Authors' abstract)

IMEOKPARIA, E.G., 1987, Metallogeny of the Mesozoic granites of Nigeria, in Current research in African earth sciences, G. Matheis and H. Schandelmeier, eds., 1987 Balkema, Rotterdam, p. 359-364. Author at Dept. Geol., Univ. Benin, Nigeria.

Fluid inclusion studies of the greisen veins from various localities in the younger granite province show that cassiterite crystallized from very dilute fluids (0.1-5 wt% NaCl) with a minimum T of 300-380°C. Sulphides crystallized from more dilute fluids in a T range 240-380°C. (E.R.)

INGEBRITSEN, S.E. and SOREY, M.L., 1988, Vapor-dominated zones within hydrothermal systems: Evolution and natural state: J. Geophy. Res., v. 93, no. B11, p. 13,635-13,655.

INGRIN, J. and DOUKHAN, J.C., 1988, New electron microscopy and infrared spectroscopy data on water in diopside (abst.): Chem. Geol., v. 70, p. 162. Authors at Lab. Structure & Propriétés de l'Etat Solide, Univ. Lille 1, 59655 Villeneuve d'Ascq cedex, France.

Water or hydroxyls (OH) have been detected by infrared spectroscopy in a number of minerals which are nominally anhydrous. This is also true for diopside (see Wilkins and Sabine 1973, Beran 1976). In order to identify how water is incorporated into diopside a joint study by infrared spectroscopy and by electron microscopy has been performed on a wet single crystal of diopside (~ 850 ppm H/Si).

The electron micrographs show that the as-received crystal contains small clinoamphibole lamellae of 1/2 and 1 cell wide parallel to the plane (010) of diopside. After annealing under argon the infrared OH stretching bands disappear above 1000°C this phenomenon is accompanied by the precipitation of small water bubbles (100Å to 3000Å) close to the amphibole lamellae. The formation of the bubbles is also accompanied by the nucleation of sessile dislocation loops with Burgers vectors 1/2[110] and 1/2[110].

It is clear that water is directly related to the presence of amphibole lamellae although the observed crystal has exactly the same infrared signature that the ones reported previously. We must then conclude that the occurrence of water or OH's dissolved into the clinopyroxene lattice still is highly questionable. Finally if there is some water truly dissolved in clinopyroxenes, the equilibrium concentration of associated water defects is appreciably smaller than the amounts reported in previous works. (Authors' abstract)

INNES, J. and CHAPLIN, R.C., 1986, Ore bodies of the Kombat mine, south west Africa/Namibia, *in* Anhaeusser, C.R. and Maske, s., eds., Mineral Deposits of Southern Africa: Geol. Soc. S. Afr., Johannesburg, v. 2, p. 1789-1805.

The Kombat Cu-Pb-Ag ore bodies comprise epigenetic, hydrothermal and metasomatic replacement and fracture-fill deposits hosted within relatively unmetamorphosed dolostone of the Hüttenberg Formation, the youngest formation of the Upper Proterozoic Otavi Group of the Damara Sequence in South West Africa/Namibia.

Mineralization is spatially associated with a regional disconformity between dolostone and younger slate, with discrete zones of penetrative deformation and with intruded bodies of feldspathic sandstone on the northern flank of the regionally extensive Otavi Valley synclinorium. Galena, chalcopyrite, bornite, and supergene chalcocite occupy a variety of loci including the matrices of tectonic and sedimentary breccias, calcitized dolostone, lenses of sandstone, shears, dilation fractures, and net-vein fractures derived through hydraulic fracturing. Compositionally layered assemblages of magnetite, hausmannite, hematite, barite, calcite, tephroite, alleghanyite, and pyrochroite, surrounded by metasomatic aureoles, occur within steep zones of tectonic transposition at many of the centers of mineralization. These layerd iron-manganese bodies are analogous to metamorphosed, volcanic exhalative deposits in respect to mineral layering, mineralogy and chemistry. The hypogene sulphides are, with the exception of minor epithermal veins, syntectonic, but the layered iron-manganese mineral assemblages may have had a precursor in the form of bedded iron and manganese carbonates and hydrous oxides.

Rock alteration is ubiquitous. Broad zones of pervasive calcitization and manganese alteration flank the ore lenses and their root zones. Sandstone lenses display extreme kaolinization and sericitization.

Preliminary studies indicate a Th for fluid inclusions in gangue associated with early sphalerite at 300°C and a T range of 200 to 280°C for the main period of chalcopyrite-bornite mineralization. A magmatic affinity for the mineralization is supported by the sulphur isotope data (mean $\delta^{34}S$ = 0.8 per mil) and by the association of the lithophile elements, Li, Be, and B, with some of the Kombat ores.

Limited Pb-isotope data, radiometric dating of the Damaran orogeny, and several physical constraints indicate that the mineralizing episode at Kombat was related to the second Damaran tectono-thermal event, placed at between 550 and 570 Ma. (Authors' abstract)

INSHIN, P.V. and ABAULINA, L.I., 1988, Carbon behavior during contact and hydrothermal alteration of black-shale zones in ore deposits: Dokl. Akad. Nauk SSSR, v. 298, no. 2, p. 432-434 (in Russian). Authors at Div. Exper. Studies of the Central Sci.-Research Geol.-Prosp. Inst. of the Color and

Precious Metals, Tula, USSR.

The paper gives a background for considerations of the formation of the C-bearing species in hydrothermal fluids. (A.K.)

ISRAELACHVILI, J.N. and McGUIGGAN, P.M., 1988, Forces between surfaces in liquids: Science, v. 241, p. 795-800. Authors at Dept. Chem. & Nuclear Engrg., Univ. California, Santa Barbara, CA 93106.

Of pertinence to problems of liquid-liquid interfaces between fluid inclusion phases. (E.R.)

ITARD, Y., 1988, A computer program to evaluate the volume of fluid inclusions: DEA dissertation, Inst. Nat'l. Polytech. de Lorraine, Nancy, 51 pp. (in French).

The Interactive Image Analyzer designed by Lapique et al. (Bull. Minéral., 1988, 111) at the CRPG allows one to digitize the contour of fluid inclusions seen in section, as well as the shape of the phases (liquid, vapor, halite) it contains. A computer program which applies the principles of mathematical morphology has been written in C language. It allows determination of the inclusion skeleton, i.e., the line inside the inclusion which, like the veins of a leaf, is characteristic of its external shape. Assuming that the inclusion has a rotation symmetry at each point of the skeleton, the inclusion volume is calculated as the sum of the volumes of each cone frustum limited by disks tangent to the inclusion contour, of the spheres centered on the skeleton triple points and of the spherical domes centered on the skeleton ends. The program allows the analyst to choose the calculation scheme which is most appropriate, depending on whether the inclusion shape is simple (spherical or cylindrical) or more complex, and is tubular or has a rotation symmetry. Preliminary applications of the program to synthetic fluid inclusions in the H_2O-NaCl and H_2O-NaOH systems are presented. (Author's abstract)

IVANENKO, V.V. and KARPENKO, M.I., 1987, ^{39}Ar-^{40}Ar data on excess argon-40 in nepheline from the Kovdor Massif, Kola Peninsula: Geokhimiya, no. 6, p. 840-846 (in Russian; translated in Geochem. Int'l., v. 25, no. 1, p. 77-82). Authors at Inst. Ore-Deposit Geol., Petrogr., Mineral. & Geochem., Acad. Sci. USSR, Moscow, USSR.

Use of nepheline in K-Ar dating of Kovdor magmatites produced ages with a range of ~ 300 My. It remains uncertain whether the nepheline contains excess argon or whether the ages correspond to alkali magmatism in the region. As excess argon is common in the Kola peninsula, and indirect evidence does not rule out argon trapping by the nepheline, two specimens with maximal K-Ar ages of ~700 My have been examined by stepwise heating and measurement of $^{40}Ar/^{39}Ar$. It is evidence that these specimens contain ~30% excess ^{40}Ar in gaseous form. When the specimens are ground, the inclusions containing the excess argon are destroyed, and then the calculated age is ~ 500 My, which approximates to the crystallization age but may exceed it if the excess ^{40}Ar is present not only in gaseous form [as inclusions] but also as single atoms trapped in the lattice. (Authors' abstract)

IVANKIN, P.F., ARGUNOV, K.P. and BORIS, Ye.I., 1988, Stages of kimberlite development and evolving conditions of diamond formation: Sovetskaya Geol., 1988, no. 3, p. 19-16 (in Russian; translated in Int'l. Geol. Review, v. 30, no. 3, p. 268-274). Authors at Central Geol. Surveying Res. Inst.

From a review of literature data on the solid and gaseous inclusions in diamond (the latter quoting Melton, but without a reference citation), the authors attempt to correlate diamond habit, size, and stage of growth with stage of melt evolution (Table 5). (E.R.)

IVANOVA, Galina, 1988, Geochemical conditions of formation of various composition wolframates [i.e., wolframites]: Bull. Minéral., v. 111, p. 97-103. Author at Vernadsky Inst. Geochem. & Anal. Chem. USSR Acad. Sci., Kosygin Str., 19, 117975 Moscow, USSR.

Study of 25 wolframite deposits from the USSR, Mongolia and Czechoslovakia permit analysis of the relations between T, P, composition of solutions and wolframite composition. According to these analyses, the deposition of wolframites varying in composition from hübnerite to ferberite occurred in the range 410-260°C under 700-1,700 bars.

These results suggest that wolframite composition does not depend on T and P and thus cannot be used as a geothermometer or a geobarometer. The chemical composition of wolframites and Fe-Mn-bearing minerals associated with wolframites of 7 W deposits was also investigated. The corresponding changes of the Mn/Fe ratio in the associated minerals (wolframite-rhodochrosite-triplite-sphalerite) was determined. According to the experimental studies on the distribution coefficients of Mn and Fe between wolframite, sphalerite and solution, the wolframite composition reflects the Mn/Fe ratio in the coexisting hydrothermal solutions. Scheelites of various genetical types of deposits formed in a wide range (600-120°C) under 1,650 to 300 bars from two types of solutions with high and low salinity, 75-30 and 15-2 wt.% eq. NaCl, respectively. (Author's abstract)

IVANOVA, G.F., NAUMOV, V.B. and KOPNEVA, L.A., 1986, Fluid-inclusion data on the physicochemical parameters for scheelite formation in various types of deposit: Geokhimiya, no. 10, 1986, p. 1431-1442 (in Russian; translated in Geochem. Int'l., v. 24, no. 5, p. 48-59, 1987). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Abstract in Fluid Inclusion Research, v. 19, p. 193. (E.R.)

IVANOVA, G.F., NAUMOV, V.B. and SUSHCHEVSKAYA, T.M., 1988, IX Symposium on fluid inclusions: Geokhimiya, 1988, no. 4, p. 602-604 (in Russian).

A summary of the papers given at the IX ECROFI meeting, May 4-6, 1987, in Oporto, Portugal. (E.R.)

JACKSON, D.H., MATTEY, D.P. and HARRIS, N.B.W., 1988a Carbon isotope compositions of fluid inclusions in charnockites from southern India: Nature, v. 333, p. 167-169.

See Fluid Inclusion Research, v. 20, p. 183, and also next item. (E.R.)

JACKSON, D.H., MATTEY, D.P. and HARRIS, N.B.W., 1988b Stable isotope studies from charnockites of south India: The source and role of CO_2 in granulite formation (abst.): Terra cognita, v. 8, p. 252. Authors at Dept. Earth Sci., Open Univ., Milton Keynes, UK.

In south India, CO_2 flushing has been favored over other models such as metamorphism of anhydrous lithologies and extraction of hygroscopic granite melts for the formation of crustal granulites. The regular occurrence of CO_2-rich fluid inclusions, thought to be trapped at peak conditions, has been used in support of this model. The abundance and $\delta^{13}C$ of CO_2 in such fluid inclusions trapped in quartz and garnet from gneiss-granulite pairs from the incipient charnockite quarries of southern India have been determined by a stepped combustion/thermal decrepitation carbon extraction technique. This technique quantifies problematic sample contamination and allows precise lithological control. Results show that CO_2 in incipient charnockite is more abundant and isotopically heavier than CO_2 in associated gneiss, providing evidence for the influx of CO_2-rich fluids during their formation. Inferred $\delta^{13}C$ values for these fluids are consistent with a mantle source. In graphite-bearing localities the abundance and isotopic composition of graphite and associated inclusion-bound CO_2 have been measured and fluid/rock volume ratios determined. (Authors' abstract)

JACKSON, D.H., MATTEY, D.P., SANTOSH, M. and HARRIS, N.B.W., 1988, Carbon stable isotope analysis of fluid inclusions by stepped heating: Geol. Soc. India Memoir 11, p. 149-158. First author at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes, MK7 6AA, UK.

A stepped heating method for analyzing the isotopic composition of carbon dioxide released from fluid inclusions in amphibolite and granulite facies rocks is described. A detailed account of the experimental method adopted is given and compared with previous studies. We illustrate the results that are obtained using this method, and also justify our data with comparison to optical heating stage observations. The advantages of adopting a stepped heating technique and its applications are discussed. (Authors' abstract)

JACKSON, D.H., SANTOSH, M., MATTEY, D.P. and HARRIS, N.B.W., 1988, Stable isotope studies on granulites from the high grade terrain of southern India (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 48-50 (also in Lunar Plan. Inst. Tech. Rept. 88-06, p. 72-74). First author at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes, MK7 6AA, UK.

This study tests the model of external CO_2-buffering and investigates the source of the carbon dioxide. Gas was extracted from fluid inclusions within quartz grains by a stepped heating technique. All samples measured show similar and simple release patterns. A maximum carbon dioxide release is found between 600°C and 800°C, which is characterized by the isotopically heaviest carbon, ranging between -12‰ and -7‰.

The data clearly show that in all gneiss-incipient charnockite pairs quartz from the charnockite contains about three times more carbon dioxide than quartz from the gneiss. The uniformity of the $\delta^{13}C$ values of both gneisses and charnockites (averaging -10 ± 2‰) from a wide area of South India indicates either that externally buffered CO_2 equilibrated with the gneiss or that the CO_2 now in the incipient charnockites represents a redistribution of the CO_2 in the precursor gneiss during charnockite formation. However we suggest an externally buffered CO_2 source rather than a closed system process. The range of $\delta^{13}C$ values is comparable to the composition of similar high P fluid inclusions preserved in upper mantle xenoliths suggesting that such fluids may contain a significant mantle component. (E.R.)

JACKSON, Mike, McCABE, Chad, BALLARD, M.M. and Van der VOO, Rob, 1988, Magnetite authigenesis and diagenetic paleotemperatures across the northern Appalachian basin: Geology, v. 16, p. 592-595.

JADHAV, G.N., PANCHAPAKESAN, V. and SAHU, K.C., 1988a, Fluid-melt inclusion studies of pegmatites in and around Dhab, Hazaribag district Bihar, India: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 203-212. Authors at Dept. Earth Sci., Indian Inst. Tech., Powai, Bombay 400076, India.

Fluid and melt inclusions observed in the quartz crystals of mica-bearing pegmatites, rare-metal pegmatites and barren pegmatites of the Dhab area in the Bihar Mica Belt were studied. The inclusions in barren pegmatites are noticeably unique but mica-rich pegmatites and rare-metal pegmatites show two types of inclusions. It is inferred that the mica-rich and rare-metal pegmatites have been intruded into a pre-existing barren pegmatite body. It is suggested that a detailed inclusion study may help in delineating the barren and productive zones in the area. (Authors' abstract)

See also same authors, 1986, Fluid Inclusion Research, v. 19, p. 194. (E.R.)

JADHAV, G.N., PANCHAPAKESAN, V. and SAHU, K.C., 1988b, A study of fluid and melt inclusions for the pegmatite occurrence of three adjoining 'Sethawa' mica mines of Nawadah district Bihar, India, <u>in</u> D. Mukhopadhyay, ed., Precambrian of the Eastern Indian Shield: Geol. Soc. of India Memoir 8, Bangalore, p. 229-237. Authors at Dept. Earth Sci., IIT, Powai, Bombay - 76, India.

Fluid and melt inclusions of Sethawa mica mines No. 1, 2 and 3 show the comparability of three disjointed pegmatites of these three mines. T zoning within a large span of thermal region and associated mineral variation have been recognized. Mica abundance appears to be restricted to a specific homogenization thermal zone. (Authors' abstract)

JAIRETH, Subhash, 1988, Hydrothermal transport of platinum and gold in the unconformity-related uranium deposits: A preliminary thermodynamic investigation: Bureau of Min. Res., Geol. & Geophys. [Australia], Record 1988/9. Author at Bureau Min. Resources, Canberra, Australia.

Published fluid inclusion data on Jabiluka, Nabarlek, Key Lake, and Rabbit Lake are quoted and used. (E.R.)

JAKOBSSON, Sigurdur and OSKARSSON, Niels, 1988, The system C-O-H at low fO_2, high P and T (abst.): EOS, v.69, p.515.

JAMBON, A., MARTY, B. and ZIMMERMANN, J.L., 1988, Comparative geodynamics of noble gases and H_2O (abst.): Chem. Geol., v. 70, p. 38. First author at U.P.M.C., Lab. MAGIE, 4 place Jussieu, 75252 Paris Cedex 05, France.

The analyses of isotopes of He, Ar and Xe in the atmosphere and the mantle shows that transfer of these species from the mantle to the atmosphere has been extensive. This is further confirmed by mass balance calculation in the case of Ar. It seems very interesting to check whether other volatile species like CO_2 and H_2O behave similarly. This can be done by normalizing volatiles to a rare gas isotope, such as ^{3}He. In the case of CO_2, it has already been shown that this species has been only partly degassed at a slow rate, similar to the present one. The $H_2O/^3He$ ratio in present day flux from the mantle can be estimated following two lines: (i) average H_2O content in normal MORB; (ii) the measured $H_2O/^3He$ ratio of 1.2 [0.8-1.6] x 10^{10} mol/mol, which gives a H_2O flux at ridges of 1 x 10^{13} mol/yr. If this flux has remained constant, a model duration of 15 Gyr would be required in order to produce the present day abundance of water at the surface. This clearly implies that the flux has decreased with time, following a behavior very similar to that of incompatible elements now stored in the continental crust. On the other hand, noble gases have been more extensively degassed with a model duration of ~200 Gyr. It results that H_2O has not been subject to the catastrophic episode of outgassing postulated for the noble gases, or that water has been preferentially lost into space during early accretional events, or that volatiles species have been massively reincorporated to the mantle on a short time scale before being slowly degassed as is observed today. (Authors' abstract)

JANARDHAN, A.S., RAJAMANI, V., RADHAKRISHNA, B.P., JAYANANDA, M., SRIKANTAPPA, C. and RAVINDRA KUMAR, G.R., 1988, Field guide; Part I, Geology: Workshop on the deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 195-286.

Indexed under "Fluid Inclusions." (E.R.)

JANARDHAN, A.S. and SRIKANTAPPA, C., 1988, Gundlupet gneiss, Nilgiri charnockites and Moyar shear zone: Workshop on the deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 335-340.

Indexed under "Fluid Inclusions." (E.R.)

JANECKY, D.R. and SEYFRIED, W.E., Jr., 1987, Transition metal mobility in oceanic ridge crest hydrothermal systems at 350°-425°C, *in* H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 657-668. First author at Los Alamos Nat'l. Lab., INC-7, MS J514, Los Alamos, NM 87545, USA.

Experimental investigations of basalt-solution reactions at conditions inferred for generation of high T oceanic ridge crest hydrothermal solutions indicate the importance of P, solution-rock ratios, and rock composition for formation of these metal-bearing solutions. At T >350°C, 400 bars P, and under rock dominated conditions, Ca and Na-metasomatism results in acid pHs and significant transition metal mobility. For Fe, Mn, and H^+, the concentrations are exponential functions of T, while Zn and Cu reach maximum concentrations at ~400°C. Variations in rock chemistry and mineralogy result in consistent variations in metasomatic reactions, aqueous SiO_2 concentration, and thereby, pH and dissolved metal concentrations. At 425°C, Na and Cl are also affected by a separate process which results in their depletion in solution by up to ~40%. Silicate alteration minerals formed during these experiments include smectite/chlorite, tremolite-actinolite, clinozoisite, and possibly albitic plagioclase. Pyrite, growing from pyrrhotite, and magnetite were also observed, consistent with phase stability predicted from H_2S and H_2 compositions of the solutions. Solution compositions from sampled East Pacific Rise hydrothermal systems for metals, H_2S, H_2, pH, minor and major elements are best modeled by our experimental data as the result of reaction of olivine-normative diabase at ~400°C, 400 bars. Higher or lower T and variations in rock composition (e.g., to ferrobasalt) produce significant variations in the solution chemistry which may be observed elsewhere. (Authors' abstract)

JANNAS, Raymond, PETERSEN, Ulrich and HOLLAND, H.D., 1988, Evolution of the ore-forming fluids at the El Indio gold-enargite bonanza, Chile (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A352. Authors at Dept. Geol. Sci., Univ. Colorado, Boulder, CO 80309.

The El Indio Au-Ag-copper lode in the high Andes of north-central Chile is the richest "Acid-Sulfate" type Au deposit; channel sample assays in excess of 1000 ppm Au are not uncommon. The mineralization history at El Indio consists of two main stages and a transition period. Enargite and pyrite are the most abundant vein minerals of Stage 1; alunite, kaolinite, and sericite are the dominant minerals in the alteration zones that destroy the texture of the Miocene ignimbrities of the wall rocks. Veins from this stage are up to twelve m wide; bands of pyrite alternate with bands of enargite and with subordinate quartz and alunite bands. During the transition from Stage 1 to Stage 2, enargite was replaced by tennantite, and sphaalerite + galena joined the progressively more complex mineral assemblage. The Au-quartz veins of Stage 2 cut the earlier structures; they are up to 5 m wide, commonly contain tellurides, and are surrounded by pervasive alteration haloes of sericite, pyrophyllite, quartz, kaolinite, and small amounts of diaspore. Most veins of Stages 1 and 2 are brecciated. Fluid inclusions in quartz from both stages have Th between 225° and 275°C. The salinity of the inclusion fluids is somewhat higher in Stage 1 than in Stage 2, but all inclusions have a salinity of <5 wt% eq. NaCl. Plots of the stability fields in log fO_2 -log fS_2 diagrams show that the solutions could have evolved from acid and oxidizing to neutral and more reducing compositions with a dissolved sulfur content $>10^{-2}$ molal. However, it is also possible that two genetically distinct solutions were responsible for the superimposed copper and Au bonanza ores. (Authors' abstract)

JEBRAK, M., TOURAY, J.C. and GIRET, P., 1988, Geochemical characteristics and genesis of fluorite deposits in Morocco: Proc. Seventh Quadrennial IAGOD Symp., E. Zachrisson, ed., E. Schweitzerbartsche Verlag., Stuttgart, p. 287-295.

Morocco is the main producer of fluorite in North Africa. The El Hammam vein, the only active mine, is located in a major shear zone. The vein is related to an active geothermal system that developed during late cooling of a crustal granite intrusion during the Autunian. As for the S-type veins in the French Hercynian basement, a precipitation model related to solution cooling may be involved. Other vein deposits, such as J. Zrahina or Aouli, display an association of barite and fluorite; mixing of hydrothermal and superficial solutions have probably been involved. In the Rif Mountain, J. Tirremi is a replacement-type deposit hosted by extruded Triassic limestone related at depth to an aborted diapir.

Based upon geochemical evidence, fluorite precipitation involved one or more of the following three processes: (1) cooling of hot brines, (2) mixing of solutions, and (3) interaction of hydrothermal solutions with limestones. Only the first process produced a fluorite deposit in the millions of tons range in Morocco. (Authors' abstract)

Th of fluorite from these various deposits are in the range 110-130°C (combination of new(?) and literature data), except for Tamazert deposit (220-300°C). (E.R.)

JEFFREY, A.W.A. and KAPLAN, I.R., 1988, Geochemistry of hydrocarbons and inorganic gases in the Gravberg-1 well (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A25-A26. Authors at Global Geochem. Corp., 6919 Eton Ave., Canoga Park, CA 91303.

Hydrocarbons detected to a depth of 6.6 km in the Gravberg-1 well have been in trace amounts, dissolved in the drilling fluid. Low concentrations of hydrocarbons from granite intervals are rich in unsaturated hydrocarbons, and may result from abiogenic synthesis from inorganic carbon species in the granite, or may be synthesized, during drilling operations, from organic precursors in the drilling fluid. Below 5 km, higher hydrocarbon concentrations in granite intervals are correlated with two different lubricants added to the drilling fluid. These additions are characterized by distinctive suites of gaseous hydrocarbons in the drilling fluid. The effects of these and other additives are pronounced in this well, due to the low concentration of indigenous hydrocarbons.

The highest concentrations of hydrocarbons were associated with several dolerite intrusions in the granite rocks. These hydrocarbons are dominated by methane, which is enriched in ^{13}C ($\delta^{13}C > -26‰$). This distinctive gas was present in both a core and cuttings, and is similar to hydrocarbons isolated from dolerite in a well in Massachusetts. The methane may have a deep origin, or may be a product of abiogenic synthesis in local crustal rocks.

Significant quantities of H_2 and helium occurring deeper than 6 km appear to have a low-T origin associated with local alteration of the granite. There is no evidence of significant amounts of upper mantle helium in Gravberg-1 gases. (Authors' abstract)

JENNINGS, E.A. and KISSIN, S.A., 1988, Sulfur isotope, fluid inclusion, and mineralogical studies of the Thunder Bay silver veins, Ontario, Canada (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A40. First author at Noranda Exploration Co., Ltd., No. 4, 2130 Notre Dame Ave., Winnipeg, MB R3H 0K1, Canada.

The Thunder Bay Ag district is comprised of two curvilinear groups of veins, the Mainland and Island Belts. The deposits vary from fully developed Ni-Co-As (five-element) assemblages (e.g., Silver Islet) through native Ag-argentite with minor sulfide assemblages.

FI from all deposits yield Th in the range 70-450°C, with frequent evidence of boiling. Salinities vary between 1 and 30 eq. wt.% NaCl with $CaCl_2$ as the dominant salt. In the Mainland Belt fracturing is seen to separate thermal peaks, indicating that ore deposits formed in distinct pulses.

Sulfur isotopic compositions of sulfides and barite range from $\delta^{34}S$ = -9.7 to +12.2 per mil, with two anomalous values near +30 per mil attributed to supergene modification. Studies of sulfide mineral pairs indicate lack of isotopic equilibrium within deposits. The low, positive values of $\delta^{34}S$ may be attributed to equilibrium fractionation of sulfur isotopes during reduction of sulfate derived from Proterozoic sea water.

Iron content in sphalerites crystallized between 80 and 120°C indicate $aS_2 = 10^{-18}$ to 10^{-25} except for copper-rich ores at Spar Island where $aS_2 = 10^{-14}$ to 10^{-18}. Crystallization occurred in near neutral to slightly alkaline solutions under relatively oxidizing conditions.

The consistency of FI, sulfur isotope, and sulfur activity data suggest that both depositional environment and hydrothermal fluid source were similar for all veins in the Thunder Bay district. The pulsatory nature of ore deposition precludes magmatic sources for the deposits, either directly or through remobilization. A long-lived, deep-seated heat source related to Keweenawan rifting is suggested as mobilizer of metalliferous connate brines. (Authors' abstract)

JEWELL, P.W. and PARRY, W.T., 1988, Geochemistry of the Mercur gold deposit (Utah, U.S.A.): Chem. Geol., v.69, no. 3-4, p. 245-265. Authors at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112, USA.

The Mercur Au deposits of west-central Utah are disseminated Carlin-type deposits which are hosted by the upper portion of the Topliff Member of the Mississippian Great Blue Limestone. Stratabound alteration and mineralization are related to sedimentary lithols. over a 60-80 m section of the Topliff Member. Hydrothermal alteration at Mercur can be separated into replacement and vein alteration assemblages. Two replacement assemblages are recognized. Jasperoid facies consist of replacement of massive limestone by SiO_2 and minor sericite and kaolinite. Argillic-facies alteration is characterized by decarbonation of silty limestones. Fluids which formed the argillic facies became progressively more reduced and acidic through reactions with carbonaceous argillaceous pyritiferous limestones. Three vein assemblages are recognized at Mercur: (1) pyrite-orpiment-orgs. ± marcasite; (2) calcite-realgar; and (3) halloysite-barite-calcite. Considerable temporal and spatial overlap exists among all hydrothermal assemblages. Varying degree of Au mineralization are associated with most styles of alteration. Fluid inclusion studies show that jasperoid-facies rocks were formed at 220-270°, hydrothermal calcite at 150-190°, and barite at 150-300°. Salinities throughout the paragenesis remained relatively constant at 5-8 eq. wt.% NaCl. A geochemical model based on fluid inclusion data, microprobe data, and mineral solys. allows constraints to be placed on the chemical characteristics of the Mercur ore-forming fluids. Jasperoid-facies rocks were formed by fluids at pH >3.6, pCO_2 (CO_2 partial P) <115 bar, and log fO_2 (O_2 fugacity) greater than -34 to -32. The argillic facies-vein assemblages were formed at pH of ~4.0, pCO_2 of ~100 bar, log fO_2 of -40.4 to -39.6 and log fH_2S (H_2S fugacity) of -3.1 to -2.7. The available data indicate ore-forming solution are near a Au soly. min. but do not allow an exact determination of the mechanism of Au deposition. (Authors' abstract)

JOHNSON, E.L., JENKINS, D.M. and LOWENSTEIN, T.K., 1988, Synthetic H_2O-CO_2 fluid inclusions in pyroxene: A model for fluid trapping at granulite facies conditions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A100. Authors at Dept. Geol. Sci., State Univ. New York at Binghamton, Binghamton, NY 13901.

We are using a unique method of producing synthetic FI to test the correspondnece between the composition of an H_2O-CO_2 fluid trapped by an inclusion with that of the ambient fluid in which it was grown. The inclusions are formed during the spontaneous nucleation and growth of orthopyroxene and clinopyroxene via the reaction:

$$2TREM + 6H_2O = 4CPX + 3OPX + 2SiO_2 \pm 4H_2O$$

This reaction provides a simplified model of the onset of granulite facies metamorphism where, in nature, fluid compositions obtained from inclusions commonly are substantially more enriched in CO_2 than those calculated from the host mineral assemblage.

The inclusions range in size from <1 µm to as large as 35 µm in long dimension. Most of the inclusions have a tubular morphology, are elongate along the c-axis of the host pyroxene grain, and often exhibit negative crystal shapes. These inclusions are believed to have been trapped either along growth spirals or in elongate hopper crystals. In addition, there are many roughly spherical to irregularly-shaped inclusions which were apparently trapped along sector twin boundaries.

Preliminary data from seven primary-textured inclusions grown at 7.0 kbar, and 800°C in an ambient fluid with $XCO_2 = 0.1 \pm 0.01$ show that the fluid within the inclusions does not match the ambient fluids. The seven inclusions analyzed had XCO_2 compositions between 0.03-0.04. Based on these data, it appears that spontaneously nucleated crystals trap inclusions that are preferentially enriched in H_2O, requiring some post-metamorphic CO_2 infiltration or recrystallization process to yield the CO_2-rich compositions observed in nature. (Authors' abstract)

JOLLIFF, B.L., PAPIKE, J.J. and LAUL, J.C., 1987, Mineral recorders of pegmatite internal evolution: REE contents of tourmaline from the Bob Ingersoll pegmatite, South Dakota: Geochimica Cosmo. Acta, v. 51, p. 2225-2232. First author at Inst. for the Study of Min. Deposits, South Dakota Sch. Mines & Tech., Rapid City, SD 55701-3995, USA.

Trace rare earth elements (REE) have been determined by radiochemical neutron activation analysis for tourmaline samples from an internally zoned, rare-element, granitic pegmatite, located in the Black Hills, South Dakota. Tourmaline samples that appear to have been fluid-derived are HREE-depleted relative to coexisting silicate-melt-derived tourmaline. Tourmaline does not exhibit any strong preference for specific REEs, rather its REE content appears to reflect the REE content of the medium from which the tourmaline crystallized. (From the authors' abstract by E.R.)

JONES, Elizabeth, 1985, Petrography and geochemistry of fluid inclusions in mineralized granites: Applications to exploration: PhD dissertation, Univ. London.

The analysis of the composition of fluid inclusions by decrepitation coupled with an inductively-coupled plasma-emission spectrometer (decrepitation-ICPS) is a new technique. Encouraging work to date on the mineralized granites of southwest England, using this technique, prompted an investigation of both the decrepitation-ICPS technique and the concept of fluid-inclusion aureoles around Sn and W mineralization in granitic rocks. Problems inherent in the decrepitation-ICPS technique, from sample preparation to the assessment and presentation of data, are discussed, and the technique, together with a petrographic examination of the fluid-inclusion populations, is applied to mineralization in Portugal, the Lake District, southwest England and Northern Ireland. (Author's abstract)

JOWETT, E.C., 1987, Formation of sulfide-calcite veinlets in the Kupferschiefer Cu-Ag deposits in Poland by natural hydrofracturing during basin subsidence: J. Geol., v. 95, p. 513-526. Author at Dept. Geol. Sci., Cornell Univ., Snee Hall, Ithaca, NY 14853-1504.

Calcite and Cu(Fe) sulfide veinlets in the Kupferschiefer ore deposits in southwestern Poland display many characteristics of antitaxial veinlets, including rails of wall rock shards from wall to wall. Crosscutting relationships demonstrate a change from sulfate to sulfide chemical stability and an evolution of stress orientation during ore formation. Bedding-plane sulfate veinlets and later bedding-plane sulfide veinlets are superseded by vertical sulfide veinlets, suggesting tectonic extension during ore formation. Thin bedding-plane calcite-(sulfide) veinlets record a return to pre-ore stress conditions after ore formation ceased. The vertical veinlets are thin and lens-shaped, typically 1-3 mm thick, 30-35 cm high, and 50-70 cm long, with orientations similar to Kimmerian-age (Triassic-Jurassic) directions. Sulfide replacement lenses cut across and are cut by vertical veinlets, suggesting contemporaneous formation after lithification. A mid-Triassic paleomagnetic age and crosscutting Alpine-age faults and dikes suggest that the veinlets and other mineralization formed during rapid subsidence in the Triassic, and not during Alpine-age uplift. A genetic model is proposed whereby the fractures originated by natural hydrofracturing caused by (1) aquathermal pressuring and (2) generation of water, CO_2, and CH_4 from the coaly organic matter in the Kupferschiefer, aided by overpressured pore fluid. It is inferred that the mineralization was accompanied by natural-gas generation and by opening of the Tethys. (Author's abstract)

JUAN, R.A., CARRANZA, E.J.M. and DOMASIG, W.F., 1987, Geology and mineralization of Jose Panganiban gold rush area, Camarines Norte: Proc., Gold '87 in the Philippine setting, Dec. 3-4, 1987, Manila, Vol. II: Manila, Philippine Inst. Mining, Metallurgy & Geol., p. xy-13/13.

Gold panning and high grading activities have been extensive in the Panganiban-Paracale Au district in the past three years. Five Au rush areas in the Panganiban area were selected and discussed in this report. Two of these areas, Paranal and Sta. Barbara, are within the gneissose Paracale Granodiorite while the rest are within the sedimentary Universal Formation, although at different stratigraphic levels.

The Au mineralization is associated with Pliocene dacite porphyry intrusions and are confined to steeply dipping to sub-vertical NNE to NE trending quartz veins except in Tidi area where NW trending quartz veins are recognized. Au occurs in the native state and may be intimately associated with the sulfide minerals consisting of pyrite, galena, sphalerite.

The comb texture and vuggy quartz veins are indicative of epithermal mineralization. Quartz-illite (sericitic) alteration, which is the main alteration type recognized and Th ranging from 225°C to 295°C indicate a paleo-depth of at least 500 m in the epithermal system. (Authors' abstract)

KALYUZHNYI, V.A., 1988, The principal achievements of and prospects for developing the study of mineral-forming fluids (problems of thermobarometry and geochemistry of ore-forming fluids) <u>in</u> V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 3-10 (in Russian).

KALYUZHNYI, V.A., BRATUS', M.D.,ZHOVTULYA, B.D., ZINCHUK, I.N., NAUMKO, I.M., PETRICHENKO, O.I. and SHIRITSA, A.S., eds., 1988, Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press, 266 pp.; 490 copies printed, price 3R, 70K (in Russian). ISBN 5-12-001072-5.

The book consists of 36 individually-authored papers, on two themes: 14 on petrological aspects of the study of magmatic inclusions, and 21 on geochemistry and thermobarometry of ore-forming fluids; the search for and assessment of mineral deposits. The titles have been translated by D.A. Brown and will be found in this volume. Translations of abstracts for 13 of these papers have been printed in Fluid Inclusion Research, vol. 18, 1985, some with modifications in author sequence or spelling, or title. These are cross-referenced here to the 1985 volume. The other 23 are papers that did not appear in the 1985 Abstract Volumes for the conference. Additional papers stemming from this same 1985 conference will be found in another 1988 book - see next item. (E.R.)

KALYUZHNYI, V.A., BRATUS', M.D., ZHOVTULYA, B.D., ZINCHUK, I.N., PETRICHENKO, I.M. and SHIRITSA, A.S., eds., 1988, Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press, 152 pp.; 500 copies printed, price 2R, 20K (in Russian). ISBN 5-12-000435-0.

The book consists of 23 individually-authored papers, 17 on: Crystallogenesis of inclusions; scientific basis and methods of studying mineral-forming fluids, and 6 on: Fluids of processes of mineral origin in sedimentary rocks. The titles of these 23 have been translated by D.A. Brown and will be found in this volume. Although apparently not mentioned in the front material of the book, most (17) of these 23 papers were presented at the 7th All-Union Conference in L'vov, 1985 (see previous item); translations of abstracts of these 17 were printed in Fluid Inclusion Research, vol. 18, 1985, some with modifications in author sequence or spelling, or title. These are cross-referenced here to the 1985 volume. The other six papers did not appear in the 1985 Abstract Volumes for the conference. Additional papers stemming from this same 1985 conference will be found in another 1988 book - see previous item. (E.R.)

KALYUZHNYI, V.A., et al., eds., 1988, Resolutions of the 7th All-Union Congress on Thermobarometry and Geochemistry of Ore-Forming Fluids (L'vov, Sept. 30-Oct. 2, 1985), in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 259-263 (in Russian).

KANAZAWA, Y., TAKENOUCHI, S. and MARIKO, T., 1988, Chemical analysis of fluid inclusion (abst.): Mining Geol., v. 38, no. 1, p. 68 (in Japanese; translation courtesy S. Takenouchi).

Chemical analyses of fluid inclusions in quartz were carried out by ion chromatograph. 15 grams of a sieved (9-16 mesh) and washed sample was crushed in an alumina-lined vibration crusher with an alumina rod. H_2O was driven off with a flow of heated N_2 gas and absorbed with anhydrone ($Mg(ClO_4)_2$). The amount of water was determined gravimetrically. Salts in fluid inclusions were leached with a 25 ml distilled water. Anions and bivalent cations were analyzed by ion chromatography and alkalies (Na and K) were determined by atomic absorption spectroscopy. Quartz samples from the Takatori and Kaneuchi W quartz veins, Korean type hydrothermal Au quartz veins and some other quartz veins were used. Cl was the most abundant cation. F and SO_4 varied according to the types of quartz veins. Anions were generally in the order Na-K-Ca-Mg-Zn-Mn in abundance. High K/Na ratio was recognized in the Korean type Au deposits. (Authors' abstract)

KARATO, Shun-ichiro, 1988, The role of recrystallization in the preferred orientation of olivine: Phys. Earth & Planet. Interior, v. 51, p. 107-122. Author at Ocean Res. Inst., Univ. Tokyo, Minamidai, Nakano, Tokyo, Japan.

The effects of recrystallization on the preferred orientation in olivine have been studied. The recrystallization mechanisms studied include grain growth, the deformation-induced grain boundary migration (DIGBM) and subgrain rotation (SGR). Grain boundary migration is involved in the first two, but not in SGR. Significant preferred orientation was found only in the latter two where dislocations are involved. The combined microstructural and fabric (preferred orientation) observations indicate that the grain boundary migration produces strong preferred orientation when the driving force is the dislocation energy but not when the grain boundary energy is the driving force. The nature of preferred orientation due to dislocation-related recrystallization (DIGBM or SGR) was found to depend on the mechanism of recrystallization. The DIGBM produces preferred orientation in which the low dislocation density grains with unfavorable orientation for easy slip dominate, thereby significantly altering the preferred orientation formed by dislocation glide. In contrast, SGR does not essentially alter the deformation fabric, and therefore the fabric associated with SGR recrystallization is related to the geometry of flow. The present results demonstrate that the existence of seismic anisotropy in the upper mantle is strong evidence for the dislocation mechanism(s) of deformation, and suggest that care must be exercised in applying the results of laboratory fabric studies made for a particular mechanism of recrystallization to the Earth's interior where the dominant mechanism(s) of dynamic recrystallization can be different. (Author's abstract)

The presence of "flats" on "bubbles" of water (added during hot-pressing of olivine aggregates) along grain boundaries is used to determine boundary migration direction. (E.R.)

KARGER, Michal, 1987, Galena-barite mineralization in Nowa Ruda syncline (Lower Silesia): Archiwum Mineralogiczne, v. 43, pt. 1, p. 53-68 (in Polish; English abstract). Author at Geol. Dept., Warsaw Univ.

Fluid inclusion data is given for the barite (~165°C). (H.E.B.)

KARL, D.M., McMURTRY, G.M., MALAHOFF, A. and GARCIA, M.O., 1988, Loihi Seamount, Hawaii: A mid-plate volcano with a distinctive hydrothermal system: Nature, v. 335, p. 532-535. First author at Dept. Oceanography, Univ. Hawaii, Honolulu, HI 96822, USA.

The initial discovery of deep-sea hydrothermal vents at the Galapagos Rift has resulted in a decade of exploration and experimentation. Subsequent discoveries in the Pacific and Atlantic ocean basins have established the importance of these features as sources of mantle-derived gases and solutes, and as loci for heat dissipation, polymetallic sulphide mineral deposition and geochemical exchange. The presence of dense communities of bacteria and specialized macrofauna has called into question the absolute role of sunlight as the principal energy source for marine organisms. Until recently, these deep-sea vents were known only at, or near, plate boundaries, but recent dredging, near-bottom-water sampling and sea-floor camera survey programs have indicated that hydrothermal vents are present at the summit of Loihi Seamount, a mid-plate, hotspot submarine volcano at the southern end of the Hawaiian island chain. Here we report results obtained from sampling two active vent fields. The fluid chemistry (especially high CO_2 and Fe), presence of alkalic lavas and iron-depositing bacteria, and absence of macrofauna suggest that mid-plate vents may differ for the hydrothermal vents found at mid-ocean ridges. (Authors' abstract)

KAUFMANN, R.S., LONG, Austin and CAMPBELL, D.J., 1988, Chlorine isotope distribution in formation waters, Texas and Louisiana: AAPG Bull., v. 72, p. 839-844. First author at Dept. Geol., Northern Illinois Univ., DeKalb, IL 60115.

Theoretically, the chlorine isotope ratio, $^{37}Cl/^{35}Cl$, can aid in identifying chloride sources and in distinguishing chloride-transport mechanisms among formation waters if ratio differences exist among samples. We measured the chlorine ratios of 18 formation-water samples from oil fields along the Texas-Louisiana Gulf Coast representing depths between 2,016 and 4,267 m. Chloride concentrations of samples ranged from 4 to 94.874 g/L, the chlorine ratios ranged from -1.24 to 0.58‰ (with respect to standard mean ocean chloride or SMOC, precision 0.12‰) and enrichment of ^{37}Cl correlates with increasing concentration. We also compared the isotope ratios of samples from within the Weeks Island salt dome with adjacent formation waters in Louisiana. All ratio measurements on the salt are between 0.1 and 0.3‰, and for the formation waters are between 0.0 and -0.22‰. The probability that the salt measurements differ from the waters is >99%. We conclude that significant chlorine isotope ratio differences exist among formation waters and between the waters and potential sources in the Gulf Coast region, and that the chlorine ratio will be a valuable tool in interpreting chloride geochemistry in this region. (Authors' abstract)

KAUL, I.K., RAO, C.N., SANYAL, Tuhina and AKHTAR, S.H., 1988, Fluorite crystallization temperatures: Evidence from thermoluminescence characteristics and fluid inclusion studies: Indian J. Geol., v. 60, no. 4, p. 258-265. Authors at Dept. Geol. & Geophys., I.I.T., Kharagpur 72130.

Fluorite samples collected from Amba Dungar, Gujarat and Belamu, West Bengal have distinctive geological associations. The thermoluminescence (TL) characteristics of the Amba Dungar fluorites show a crystallization T of the order of 113°C, while those for the Belamu fluorite shows higher T of crystallization (~265°C). The fluorites from both places may thus be said to have crystallized during the waning phases of hydrothermal activity. The absolute T of crystallization determined from fluid inclusion geothermometry agree with these findings. (Authors' abstract)

KAYA, Ali and FRIEDMAN, G.M., 1988, Epigenetic and deep-burial dolomitization of Middle Ordovician Antelope Valley Limestone (Pogonip Group), central Nevada (abst.): AAPG Bull., v. 72, p. 205. First author at Brooklyn College & Gradate Sch. of City Univ. N.Y., Brooklyn, NY.

Pervasive dolomitization of strata in the Antelope Valley Limestone (AVL) is chiefly related to faulting and burial depth. At Clear Creek Canyon and Keystone Canyon, north-south and northeast-southwest-trending parallel extensional faults juxtapose entirely dolomitized sections of the AVL and shaly units of Cambrian, Ordovician and Silurian age. Magmatic intrusives and related quartz veins that cut this formation are post-dolomitic and not responsible for dolomitization. At Martin Ridge, dolomitization gradually decreases with increasing distance from the fault zones. At Lone Mountain, dolomitized strata are conformable with non-dolomitic units and their associations with faulting have not been observed.

Petrographic study indicates that xenotopic mosaics of dolomite crystals with curved and penetrative boundaries and undulose extinction are the dominant kinds of crystals in pervasively dolomitized strata. These mosaics postdate stylolites, and replaced calcite-filled veins as well as idiotopic dolomite crystals in selectively dolomitized particles. These mosaics are postdated by saddle dolomite, and by quartz and calcite veins of probably hydrothermal origin. Most of the dolomites are uniformly dull or nonluminescent, indicating a possible high iron content typical of burial dolomite. Th of two phase fluid inclusions range from 105° to 285°C. Thermal alteration indices (2.7-3.1) and vitrinite reflectance data (R = 0.93-1.13) are consistent with high Th. (Authors' abstract)

KEITH, T.E.C. and BARGAR, K.E., 1988, Petrology and hydrothermal mineralogy of U.S. Geological Survey Newberry 2 drill core from Newberry caldera, Oregon: J. Geophys. Res., v. 93, no. B9, p. 10,174-10,190. Authors at U.S. Geol. Survey, Menlo Park, CA.

U.S. Geological Survey Newberry 2 was drilled to a depth of 932 m within Newberry caldera. The bottom-hole T of 265°C is the highest reported T of any drill hole in the Cascades region of the United States. Fluid inclusions in quartz and calcite indicate that T in the past have been higher than at present, most likely due to local confining P between impermeable lava flows. Alteration and leaching in the basal 2 m are unique and have led to the postulation of a localized two-phase fluid zone consisting mainly of steam and CO_2. The hydrothermal system of Newberry 2 is a simple evolving system associated with the evolution of Newberry Volcano. Only a few localized highly altered intervals where fracturing controlled fluid access occur in the core. There are no crosscutting fractures to indicate multiple hydrothermal systems. Chemical analyses of altered rocks and equivalent fresh rocks indicate that little chemical migration has taken place. (From the authors' abstract)

KELLY, W.C., NISHIOKA, G.K., LOHMANN, K.C. and RYE, R.O., 1988, Origin and significance of petroliferous calcite veins, White Pine district, northern Michigan (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A143. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

Calcite veins crosscutting the ore zone at White Pine record the circulation of oil and aqueous brines long after the main mineralization event. Dated at roughly 1047 ± 35 Ma (Ruiz and et al., 1984), these veins formed during uplift and erosional removal of as much as 7 km of sandstone cover from the district in late Jacobsville time.

Fluid T (up to 93°C) and P (Ca. 100-800 bars) varied widely, presumably reflecting reduction of cover thickness through time. The vein calcites have $\delta^{13}C$ values of -6.1 to -30.0‰, $\delta^{18}O$ values of 9.0 to 24.0‰, and inclusion water δD values of -56 to -101‰. These data suggest that the fluids were evolved meteoric waters recharged at high elevations but, additionally, oxidation of Nonesuch organic matter probably contributed to some of the anomalously low δD and $\delta^{13}C$ values determined. Salinities of the fluids are imprecisely known, but varied from highly concentrated Na-Ca-Cl brines to nearly fresh water.

Having circulated through redbeds of the Oronto section, the vein waters caused local oxidation and selective leaching of native copper from the older ore beds. Minor Cu-Fe sulfides in the veins are thought to have derived their sulfur chiefly by reduction of sulfate imported in the redbed waters.

Superb primary petroleum inclusions, well stratified in the vein calcites, indicate that oil migration continued throughout this period of late veinage, the migration probably driven by the same compressional tectonism responsible for the vein structures themselves. (Authors' abstract)

KENNEDY, B.M., 1988, Noble gases in vent water from the Juan de Fuca Ridge: Geochimica Cosmo. Acta, v. 52, p. 1929-1935. Author at Dept. Physics, Univ. California, Berkeley, CA 94720, USA.

Hydrothermal vent fluids collected with the DSRV Alvin from the southern limb of the Juan de Fuca Ridge are chemically unique, having chloride concentrations ~2 times ambient seawater. The same fluids contain noble gases in relative abundances like 2°C air-saturated seawater, the expected recharge composition. However, the absolute noble gas abundances are depleted by ~30% relative to seawater. The combination of very high chloride and moderately depleted noble gases appears to require the formation of a Cl-rich, gas-free brine by phase separation. This brine is mixed with recharge seawater at T in excess of ~340°C and, therefore, deep in the hydrothermal system. (Author's abstract)

KENNEDY, B.M., REYNOLDS, J.H. and SMITH, S.P., 1988, Noble gas geochemistry in thermal springs: Geochimica Cosmo. Acta, v. 52, p. 1919-1928. First author at Dept. Physics, Univ. California, Berkeley, CA 94720, USA.

The composition of noble gases in both gas and water samples collected from Horseshoe Spring, Yellowstone National Park, was found to be depth dependent. The deeper the sample collection within the spring, the greater the enrichment in Kr, Xe, radiogenic ^{4}He, and ^{40}Ar and the greater the depletion in Ne relative to ^{36}Ar. The compositional variations are consistent with multi-component mixing. The dominant component consists of dissolved atmospheric gases acquired by the pool at the surface in contact with air. This component is mixed in varying degree with two other components, one each for gas and water entering the bottom of the pool. The two bottom components are not in equilibrium.

In Horseshoe Spring, the bubbles entering at the bottom strip the atmospheric-derived pool gases from the surrounding water while en route to the surface. If the original bottom bubbles are noble gas poor, as in the case of Horseshoe, the acquired pool gases can then quickly obliterate the original bubble composition. These results are used to demonstrate that Yellowstone spring surface gas samples, and perhaps similarly sampled thermal springs from other hydrothermal systems, have gas abundances that depend more on spring morphology than processes occurring deeper in the hydrothermal system. (Authors' abstract)

KERKHOV, A.M. van den - See van den KERKHOV

KERRICH, R., 1987, The stable isotope geochemistry of Au-Ag vein deposits in metamorphic rocks, <u>in</u> Kyser, T.K., ed., Short Course in Stable Isotope Geochemistry of Low Temperature Fluids: Min. Soc. Canada Short Course Handbook, v. 13, p. 287-.

Discusses the stable isotope and Th data derived from fluid inclusions as an aid in the interpretation of Au-Ag vein deposits in metamorphic rocks. (H.E.B.)

KERRICH, R. and KAMINENI, D.C., 1988, Characteristics and chronology of fracture-fluid infiltration in the Archean, Eye Dashwa Lakes pluton, Superior Province: Evidence from H, C, O-isotopes and fluid inclusions: Contrib. Mineral. Petrol., v. 99,. p 430-445. First atuhor at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan, Canada S7N OWO.

The Archean Eye Dashwa Lakes pluton (2672 ± 24 Ma) has domains of mineralogically fresh isotropic granite, domains that have undergone bulk hydrothermal alteration, and at least eleven sets of sequential fracture arrays, each with distinctive mineral assemblages. Fresh granite is characterized by whole rock $\delta^{18}O$ = 8.1 to 8.6 and primary magmatic quartz-feldspar (+1.3‰), quartz-biotite (5.2 to 5.4‰) and quartz-magnetite (+9.8‰) fractionations. Magmatic fluids had a calculated isotopic composition of $\delta^{18}O$ = 7.9 ± 0.5, and δD = -80 ± 5. These isotopic volumes of the granite have not experienced significant incursion of external thermal waters. Pegmatites, quartz-molybdenite veins, and phlogopite-muscovite coated fractures are sporadically distributed in the granite, and were precipitated from high-T 'magmatic' fluids where $\delta^{18}O$ = 8.0 to 10.3 and δD = -80 ± 5.

The most abundant variety of fracture filling assemblage is epidote-quartz-chlorite ± muscovite: fractures are bounded by domains of mineralogically similar bulk hydrothermal alteration of the granite. These minerals formed at 160 to 280°C, in the presence of NaCl, and NaCl-$MgCl_2$ brines (up to 25 wt% NaCl eq.) of probable evolved marine water origin ($\delta^{18}O$ = +0.4 to +3.8, δD = -10 to -35) undergoing transient boiling. Upper plateau $^{40}Ar/^{39}Ar$ ages for the muscovite are 2650 ± 15 Ma. Sequentially in the chronology of fracture-infiltration events, calcite-fluorite veins were deposited form boiling fluids at 340 to 390°C, isotopically characterized by $\delta^{18}O$ = 4.7 and $\delta^{13}C$ = -5; and rare prehnite-chlorite lined fractures formed at 250 to 290°C. A generation of adularia-bearing veins precipitated at 140 to 230°C, from $CaCl_2$-NaCl brines, where $\delta^{18}O$ = 0 to -6.5 and δD = -10 to -30. Incremental $^{40}Ar/^{39}Ar$ age spectra on the K-feldspar yield an upper plateau of 1100 Ma. Subsequently, hematite developed during reactivation of earlier fractures, at 140 to 210°C in the presence of fluids characterized by $\delta^{18}O$ = -0.4 to -5.4 and δD = -15 to -25. Arrays of open fractures partially occupied by gypsum and goethite reflect a fluid infiltration event at T <50°C. Many of the earlier generations of fracture minerals have transgranular fracture infillings which record the presence of low T (99-190°C), hypersaline $CaCl_2$-NaCl brines. Narrow fractures lined with clays ± calcite are sites for seepage of modern groundwaters. The isotopic signature of clay($\delta^{18}O$ = 12 to 20, δD = -80 ± 5) plots near the line for modern kaolinites, confirming its formation in the presence of recent surface waters. Calcites coexisting with the clay minerals, and in fractured pegmatite show a common isotopic signature ($\delta^{18}O$ = 23 ± 0.5, $\delta^{13}C$ = -13.6), indicating precipitation from modern groundwaters, where reactivated fractures have acted as conduits for infiltration of surface waters to depths of ~200 m. Intermittent fracture-infiltration has occurred over 2.7 Ga. The early sequences of fracture-related fluid flow are interpreted in terms of devolatilization of the granite, followed by thermal contraction fracturing, incursion of marine water and convective cooling in the Archean. Hematite and adularia fracture fillings correspond to a stage when meteoric water infiltrated the volcanic-plutonic terrain during Proterozoic and later times. Episodic fracture-fluid expulsion events may have been driven by seismic pumping, in response to magmatically and tectonically induced stresses within the Shield, with surface waters penetrating to depths of ~15 km in the crust. (Authors' abstract)

KESLER, S.E., JONES, L.M. and RUIZ, Joaquin, 1988a Strontium isotopic geochemistry of Mississippi Valley-type deposits, East Tennessee: Implications for age and source of mineralizing brines: Geol. Soc. Am. Bull., v. 100, p. 1300-1307. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

Strontium isotopic ratios of wall-rock, ore, and gangue minerals from the Mascot-Jefferson City, Copper Ridge, and Sweetwater Mississippi Valley-type (MVT) districts and from the Lost Creek barite deposit in East Tennessee were measured in an effort to determine the age of this mineralization and its relation to the tectonic evolution of the Appalachian orogen. The Lower Ordovician Knox Group, which hosts the MVT mineralization, contains limestones and dolomite karst breccias with ^{87}Sr/^{86}Sr ratios of 0.70900 to 0.70916 that are similar to those of Early Ordovician sea water. Primary (diagenetic) Knox dolomite, a well as "recrystalline" dolomite, which formed by later alteration of limestone, exhibits ^{87}Sr/^{86}Sr ratios of 0.70930 to 0.71024, reflecting varying degrees of contamination by solutions with more radiogenic strontium. ^{87}Sr/^{86}Sr isotopic ratios of mineralization in the districts increase in the order Lost Creek, Sweetwater, Copper Ridge, Mascot-Jefferson City and extend to values significantly higher than those of the enclosing rocks.

Of the three possible source basins for the MVT brines, the Late Proterozoic Ocoee, Cambrian Luttrell, and Ordovician Sevier basins, the Sevier basin appears to be the only one that could have supplied brines of the appropriate composition at geologically reasonable times. Estimates of the change with time in the isotopic composition of Sevier basin brines indicate that the maximum ages of the Lost Creek, Sweetwater, Copper Ridge, and Mascot-Jefferson City mineralization are 520, 460, 405, and 395 m.y., respectively. Comparison of fluid-inclusion T for the Sweetwater and Mascot-Jefferson City mineralization with the thermal evolution curve for the Sevier basin supports these estimates. These ages suggest that the Lost Creek barite mineralization formed as an exhalative deposit in the Sevier basin and that the Sweetwater fluorite-barite mineralization formed during the later part of the Taconic orogeny. The Copper Ridge and Mascot-Jefferson City mineralization could have formed either prior to or during the Alleghanian orogeny (but prior to deformation of the enclosing rocks), depending on the rate of isotopic evolution of the Sevier basin brines. (Authors' abstract)

KESLER, S.E., JONES, L.M. and RUIZ, J., 1988,✓ Strontium and sulfur isotope geochemistry of the Galeana barite district, Nuevo Leon, Mexico: Econ. Geol., v. 83, p. 1907-1917. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

The authors document their unsuccessful attempts at fluid inclusion microthermometry and decrepitate analysis of fluid inclusions in barite. (H.E.B.)

KHARAKA, Y.K., 1988, Geochemical modelling of interactions between metal-rich brines and sediments from central Mississippi Salt Dome basin, USA (abst.): Terra cognita, v. 8, p. 190. Author at U.S. Geol. Survey, Menlo Park, CA, USA.

The central Mississippi Salt Dome basin is one of the very few areas worldwide with high concentrations of Pb, Zn and other metals in its brines. Detailed inorganic and organic chemical and isotope analyses of water and gas samples from six oil fields in this basin were conducted to study the inorganic and organic complexes responsible for the high concentrations of these metals. The samples were obtained from production zones consisting of sandstone and limestone that range in depth from 1,900 to 4,000 m (70° to 120°C) and in age from Late Cretaceous to Late Jurassic.

Results show that the waters are dominantly bittern brines with extremely high salinities that range from 160,000 to 320,000 mg/L total dissolved solids. They are Na-Ca-Cl-type waters with very high concentrations of Ca (up to 48,000 mg/L) and other alkaline-earth metals, but with low concentrations of aliphatic acid anions. The concentrations of metals in many water samples are very high, reaching values of 70 mg/L for Pb, 245 mg/L for Zn, 465 mg/L for Fe and 210 mg/L for Mn. The samples with high metal contents have extremely low concentrations (<0.02 mg/L) of H_2S. Samples obtained from Smackover Formation (limestone) have low metal contents, but very high concentrations (up to 85 mg/L) of H_2S. (Continued)

Computations with SOLMINEQ.87 give the following results: 1) Pb and Zn are present in brines mainly as $PbCl_4^{--}$ and $ZnCl_4^{--}$, respectively; 2) the concentrations of metal complexes with aliphatic acid anions and reduced S species are minor; 3) organic acid anions affect the pH and buffer capacity of the waters at subsurface conditions; and 4) galena and sphalerite solubilities control the concentrations of Pb and Zn in these waters. (Author's abstract)

KHARAKA, Y.K., DeBRAAL, J.D. and AMBATS, Gil, 1988, Reactive organic species in subsurface waters: Implications for geochemical modeling (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Authors at U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94025.

High concentrations (<10,000 mg/L) of mono- and dicarboxylic acid anions, phenols and other reactive organic species are present in formation waters from sedimentary basins, especially those from relatively young reservoir rocks at subsurface T of 80° to 100°C. The original concentrations likely were higher because these organics are degraded by bacteria (t <80°C) and decarboxylated to CO_2 and natural gas thermally. Estimated field decarboxylation rates yield half-life values of ~20 million years at 100°C. Knowledge of the spatial and temporal distribution of these organics is required for modeling water-rock interactions in sedimentary basins. Computations using the geochemical code SOLMINEQ.88 indicate that reported organic species (1) can control the pH, Eh, and buffer capacity of subsurface waters, (2) probably are not important as complexing agents for Pb, Zn and U, and (3) play a more important role in the geochemistry of Fe, Mn and possibly Al. We believe that new organic species will be identified because methodologies for sampling and analysis are improving. (Authors' abstract)

KHITAROV, N.I., LEBEDEV. Ye.B., DORFMAN, A.M. and BAGDASAROV, N.Sh., 1987, The compressibility of water up to 5 kbar and 1000°C: Geokhimiya, no. 8, p. 1108-1114 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 3, p. 40-45).

KHRENOV, A.P., OKRUGIN, V.M., FEDOTOV, S.A., ARCULUS, R.J., DAVIDSON, J., HALLIDAY, A.N., and HOLDEN, P., 1988, Klyuchevskoy: a big, basaltic, explosive, fast-growing stratovolcano in Kamchatka, U.S.S.R. (abst.): EOS, v.69, p.267. First author at Inst. Volcanology Petropavlovsk, Kamchatsky, 683006, USSR.

Klyuchevskoy (4750m high) is located in the central Kamchatka Depression, close to the onland projection of the intersection of the Aleutian and Kamchatka trenches with the Emperor Seamount chain. The volcano is characterized by a remarkably high effusion rate (0.7 m^3s^{-1} cf. Kilauea 3 m^3s^{-1}) of predominantly pyroclastic, high-to medium-MgO (9-4.3 wt %), high-SiO_2 (52.3-53.6 wt %) basalts. Phenocryst assemblages are olivine, clino- and orthopyroxene, plagioclase and spinel with groundmass pigeonite. Cumulate fragments have the same mineralogy and appear to confirm the relatively early appearance of opx in the crystallization sequence. Molar projections of bulk compositions fall to the olivine-rich side of the 1 bar, experimentally determined cotectics and peritectics in the ol-pl-cpx-SiO_2 system.

Abundant fluids trapped within glass inside phenocrysts and cumulate phases appear to be H_2O rich, analogous to some parageneses along the volcanic front in Honshu (Japan). The combination of radiogenic Nd, early opx saturation and volatile plus LILE enrichment is indicative of an unusual blend of highly refractory source (possibly harzburgite at melt departure) with selective LILE & H_2O enrichment. (From the authors' abstract)

KIM, H.-T. and FREDERICK W.J., Jr., 1988, Evaluation of Pitzer ion interaction parameters of aqueous mixed electrolyte solutions at 25°C. 2. Ternary mixing parameters: J. Chem. Eng. Data, v. 33, p. 278-283.

KIM, Y.K., WILLIARD, J.W. and FRAZIER, A.W., 1988, Solubility relationship in the system $NaNO_3$-NH_4NO_3-Urea-H_2O at 0°C: J. Chem. Eng. Data, v. 33, p. 306-309.

KIMBALL, K.L. and HARPER, G.D., 1988, Introduction to special section on subseafloor metamorphism: J. Geophy. Res., v.93, n.B5, p.4521, First author at Dept. of Geol., Rensselaer Polytechnic Inst., Troy, NY.

This special section includes many papers of pertinence to students of inclusions in metamorphic rocks. A few are separately listed in this volume, by author (E.R.).

KINNUNEN, Kari, 1986, A simple method for pilot fluid inclusion studies: Geologi (Helsinki), v. 38, p. 133-134 (in Finnish; English abstract).

A "ring stage" is described for the examination of broken fragments at high magnification. The fragments are "glued" onto a thin coverglass with index liquid; the coverglass is then inverted and mounted on a metal ring on a glass slide, with the grains held on by capillarity. Observation is through the coverglass (see diagram). This procedure results in a horizontal coverglass, permitting optimum optical observation and the use of high magnification, and avoids possible damage to objectives. (E.R.)

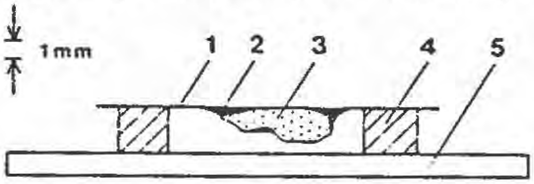


Fig. 1. Construction of the ring stage. 1. Cover glass. 2. Immersion liquid. 3. Specimen. 4. Ring section. 5. Object glass.

KIRAN, E., ed., 1988-on, The Journal of Supercritical Fluids: PRA Press, Polymer Research Assoc., Inc., P.O. Box 42375, Cincinnati, Ohio 45242, USA.

Described as "A new international journal devoted to the fundamental and applied aspects of supercritical fluids and processes", this journal should contain much that is pertinent to understanding the high T-P behavior of fluid inclusions. (E.R)

KIRBY, C.S., DRISCOLL, A.J., Jr., BODNAR, R.J. and LAW, R.D., 1988, Importance of fluid composition in the mylonitization process: A shear zone as a conduit for $CaCl_2$-NaCl brines (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A332. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Theoretical models and geological observations suggest that fluids play an important role in the evolution of mylonites. Fluids transfer components into and out of developing mylonites and may significantly affect mechanical properties of rocks. Recent studies have employed properties of pure water to calculate mineral stabilities and volumes of fluids passing through shear zones. However, fluid inclusion studies indicate that highly saline brines are often involved in the mylonitization process, and these brines may have chemical and physical properties very different than pure water. For example, the solubility of quartz in an aqueous brine at elevated T and P is considerably higher than its solubility in pure water at the same P-T conditions. Other minerals such as sulfides also exhibit increased solubility in brines. This increased solubility allows smaller fluid volumes to carry an equivalent amount of dissolved minerals in solution. Thus, knowledge of the compositions of formation fluids is required to develop quantitative chemical models that accurately describe the role of fluids in the development of mylonites.

High salinity fluid inclusions in mylonitic quartz veins in the Fries Fault, a crystal plastic shear zone in the Blue Ridge Province of southwestern Virginia, have been examined using microthermometry and crushing studies. Quartz veins in the shear zone contain fluid inclusions in the following sites: 1) within grains, 2) along subgrain boundaries, 3) along grain boundaries and, 4) in late fractures oblique to the mylonitic foliation. Owing to the small size of subgrain and grain boundary inclusions, microthermometric data were obtained mostly from those inclusions within grains. Eutectic T ranged from -60° to -50°C, melting T were approximately -21°C, and Th of liquid-vapor inclusions (to the liquid phase) ranged from 78° to 300°C, with most between 100° to 160°C. Freezing data suggest fluid compositions within the system $CaCl_2$-$NaCl$-H_2O with a salinity of ≈ 22 wt % NaCl eq. Non-condensable gases were not observed in these inclusions. Inclusions in late fractures oblique to the mylonitic foliation are thought to have formed in the latest stages of mylonitization of post-mylonitization. (Authors' abstract)

KIROV, G.K. and PETROV, P.P., 1988, Taxonomy and informativity of inclusions in man-made quartz crystals: Comptes-rendus de l'ABS, 1988, no. 2, p. 89-90 (in English).

The inner morphology of a large number of quartz crystals grown in the laboratory under various conditions and of some industrial crystals were studied and identical types of inclusions are found in both cases: (1) solid inclusions of two kinds: simply adhered, found in any crystal and reaching up to 10 μm; and grown after adhering, which are rare and are observed in the industrial crystals only, they reach up to 100 μm; (2) fluid inclusions containing gas bubbles. They are numerous and are found in every crystal. Seven types of such inclusions are distinguished differing in orientation, size and mechanism of formation. (Abstract by S. Aslanjan)

KISLITSYN, V.G., SIDIKOV, S., SULTANKHODZHAYEV, A.N., TOLTSIKHIN, I.N. and CHERNOV, I.G., 1987, Ar and He isotopes in rocks, inclusions, and water from the Tashkent geodynamic test area: Geochem. Int'l., 1988, v. 25, no. 3, p. 97-103.

Translation of full paper abstracted in Fluid Inclusion Research, v. 20, p. 198. (H.E.B.)

KISSIN, S.A., 1988, Fluid inclusions in meteorite impact structures and their relevance to the Sudbury structure (abst.): Canadian Continental Drilling Program Rept. 88-2, Scientific Drilling: The Sudbury Structure (Proc. of a workshop, Oct. 6th & 7th, 1988), p. 18. Author at Dept. Geol., Lakehead Univ., Thunder Bay, Ont. P7B 5E1, Canada.

In the case of the Sudbury structure the genetic controversy has centered on a number of points, but one of the most important is the nature of the Onaping Formation. Resolution of the question of its igneous or impact origin is crucial to the question of an endogenic (terrestrial process) or exogenic (extraterrestrial process) origin of the Sudbury structure. Fluid inclusions in breccias and melts of the Onaping Formation should provide important evidence as to the genesis of the host rocks. A vast literature should provide a means of identifying inclusions formed in an igneous environment or modified by metamorphism. However, inclusions in impact-derived materials are of low salinity and are CO_2-free. The inclusions trapped in impact melts may characteristically exhibit metastable behavior. (From the author's abstract)

Also includes reviews of the inclusion studies made by others at Vredefort, Charlevoix, Carswell, and Haughton. (E.R.)

KISSIN, S.A., JENNINGS, E.A., SHERLOCK, R.L. and McCUAIG, T.C., 1988, The genesis of silver vein deposits in the Thunder Bay area, northwestern Ontario (abst.): Ontario Mines & Minerals Symp., Geosci. Res. Seminar 1988, Abst., p. 7. First author at Dept. Geol., Lakehead Univ., Thunder Bay, Canada.

The Thunder Bay Ag district is comprised of two curvilinear groups of veins, the Mainland and Island Belts. A separate subdistrict occurs in the Schreiber-Terrace Bay area, where Pb-Zn-Ag veins cut Archean rocks. The deposits vary from fully developed Ni-Co-As (five-element) assemblages (e.g., Silver Islet) through native Ag-argentite with minor sulphide assemblages.

Fluid inclusions from all deposits yield Th in the range 70-450°C, with frequent evidence of boiling. Salinities vary between 1 and 30 eq. wt.% NaCl with $CaCl_2$ as the dominant salt. In the Mainland Belt fracturing is seen to [two?] separate thermal peaks, indicating that deposits formed in distinct pulses.

S isotopic compositions of sulphides and barite range from $\delta^{34}S = -9.7$ to +12.2‰, with two anomalous values near +30‰ attributed to supergene alteration. Studies of sulphide mineral pairs indicate lack of isotopic equilibrium within deposits. The low, positive values of $\delta^{34}S$ may be attributed to equilibrium fractionation of S isotopes during reduction of sulphate derived from Proterozoic seawater.

Fe contents in sphalerite crystallized between 80 and 120°C indicate $aS_2 = 10^{-18}$ to 10^{-25} except for Cu-rich ores at Spar Island where $aS_2 = 10^{-14}$ and 10^{-18}. Crystallization occurred in near neutral to slightly alkaline solutions under relatively oxidizing conditions.

The consistency of fluid inclusion, S isotope and S activity data suggest that both depositional environment and hydrothermal fluid source were similar in all veins in the Thunder Bay district. The pulsatory nature of ore deposition precludes magmatic sources for the deposits, either directly or through remobilization. A long-lived, deep-seated heat source related to Keweenawan rifting is suggested as mobilizer of metalliferous connate brines.

Fluid inclusions in drill core from the Shuniah, Porcupine and Keystone mines indicate that within particular growth zones Th increase with depth. These data support a source at depth for the solutions, but indicate that conditions at the site of deposition controlled precipitation of the ores. (Authors' abstract)

KIYOSU, Yasuhiro and YOSHIDA, Yutaka, 1988, Origin of some gases from the Takinoue geothermal area in Japan: Geochem. J., v. 22, p. 183-193. First author at Dept. Earth Sci., Sch. Sci., Nagoya Univ., Chikusa, Nagoya 464, Japan.

Chemical and isotopic compositions were analyzed on geothermal steam from fumaroles and wells in the Takinoue geothermal area. The distribution of D and ^{18}O in water samples suggests that the fumarole steam discharge is formed from the rising geothermal fluid through a single-step steam separation process at ~150-240°C. On the basis of N_2/Ar, He/Ar and CO_2/N_2 ratios, and $\delta^{13}C$ values of CO_2 in steam, it is concluded that the gas components dissolved in the Takinoue geothermal waters are mixtures of magmatic gases and meteoric waters. (Authors' abstract)

KJARSGAARD, B.A. and HAMILTON, D.L., 1988, Liquid immiscibility and the origin of alkali-poor carbonatites: Mineral. Mag., v. 52, no. 364, p. 43-55.

See next item. (E.R.)

KJARSGAARD, B.A., HAMILTON, D.L. and BROOKER, R., 1988, Liquid immiscibility and the origin of alkali-poor carbonatites (abst.): Terra cognita, v. 8, p. 66. Authors at Dept. Geol., The Univ. Manchester, M30 9PL, UK.

The work on liquid immiscibility in carbonate-silicate systems of Freestone and Hamilton (1980) has been extended to include alkali-poor and alkali-free compositions. Immiscibility is shown to occur on the joins albite-calcite at 2, 5 and 15 kbar, and anorthite-calcite at 2 and 5 kbar. Currently the effects of MgO and higher P are being investigated. Preliminary data indicates that addition of MgO increases the liquidus T of the system and decreases the size of the two-liquid field. Increased P expands the miscibility gap and favors Mg partitioning into the carbonate liquid. These results make it possible to interpret ocellar structure between calcite-rich spheroids in lamproite or kimberlite host rock as products of liquid immiscibility. The common sequence of rock types found in carbonatite complexes of melilitite-ijolite-urtite-phonolite is interpreted as being the result of both fractional crystallization and liquid fractionation, the corresponding carbonatite composition changing from nearly pure $CaCO_3$ (±$MgCO_3$) progressively to natrocarbonate. A carbonate melt cooling in isolation will suffer crystal fractionation, the residual liquid producing the rarer ferrocarbonatites etc., whilst the crystal accumulate of calcite (dolomite) plus other phases such as magnetite, apatite, baryte, pyrochlore etc., are the raw material for the coarse-grained intrusive carbonatites commonly found in ring complexes. (Authors' abstract)

KLATT, E., HOERNES, S. and RAITH, M., 1988, Characterization of fluids involved in the gneiss-charnockite transformation in southern Kerala (India) (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 57-59 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 81-83).

See Klatt and Raith, 1987, in Fluid Inclusion Research, v. 20, 1987. (E.R.)

KLEIN, T.L. and CRISS, R.E., 1988, An oxygen isotope and geochemical study of meteoric-hydrothermal systems at Pilot Mountain and selected other localities, Carolina slate belt: Econ. Geol., v. 83, p. 801-821. First author at U.S. Geol. Survey, Reston, VA 22092.

Several epigenetic mineral deposits in the Carolina slate belt are intimately related to meteoric-hydrothermal systems of late Precambrian and early Paleozoic age. Low ^{18}O rocks correlate well with zones of strong silicic alteration and alkali leaching accompanied by high alumina minerals (sericite, pyrophyllite, andalusite ± topaz) and anomalous concentrations of Cu, Mo, Sn, B, and Au. The fluid calculated to be in equilibrium with the lowest ^{18}O quartz veins and country rocks at 300° ± 50° would have $\delta^{18}O \sim -4.5 \pm 2.0$ per mil, whereas analyses of radiating pyrophyllite indicate equilibrium with a fluid having $\delta D \sim -30$ per mil, consistent with a slightly ^{18}O-shifted, low-latitude meteoric water. Subsequent greenschist metamorphism caused intermineral isotopic reequilibration in several samples and may have modified preexisting alteration assemblages, but it did not destroy the large $\delta^{18}O$ anomaly produced by meteoric-hydrothermal activity. (From the authors' abstract by E.R.)

KLEMD, Reiner, 1988, Fluid inclusions: Die Geowissenschaffen, v. 6, no. 6, p. 182-186 (in German).

A review with 14 references, including SEM photographs of dms from Varkenskraal, South Africa: K-feldspars; gypsum (or anhydrite); muscovite; and calcite. (E.R.)

KNAUTH, L.P., 1988, Origin and mixing history of brines, Palo Duro Basin, Texas, U.S.A.: Applied Geochem., v. 3, p. 455-474.

KNIGHT, C.L.E., 1988, Critical properties of NaCl-H_2O solutions: MS thesis, Virginia Polytech. Inst. & State Univ.

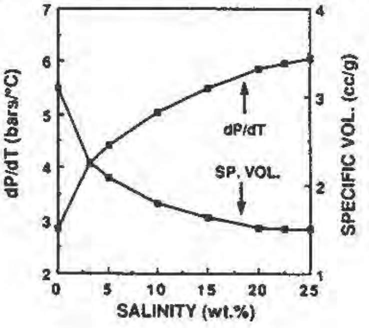
Critical properties of the NaCl-H_2O fluid system are of fundamental interest to a variety of geochemical applications including fluid inclusion studies, numerical modeling of hydrothermal systems, and development of theoretical models for two-component fluid systems. Although many workers have expressed interest in NaCl-H_2O fluid critical properties, most studies have been limited to small compositional ranges with little agreement among data sets at higher salinities. Critical densities are recorded in only one of these reports, and no studies have determined the locations of NaCl-H_2O critical isochores (PT projections of critical densities). Furthermore, no studies to date have determined critical properties of NaCl-H_2O solutions in excess of room T saturation (26.4 wt.% NaCl).

Using the synthetic fluid inclusion technique, critical properties have been determined for NaCl-H_2O compositions from 0.0 to 30.0 wt.% NaCl. Critical T and P range from 374°C to 220 bars for pure H_2O to 665°C and 930 bars for 25 wt.% NaCl. Critical T for 27.5 and 30.0 wt.% NaCl are >725°C. Critical densities and isochores were calculated using the equation of Bodnar (1985) relating molar volumes of NaCl-H_2O solutions to PTX properties above 1000 bars and below 1000°C. Critical densities for compositions from 0.0 to 25 wt.% NaCl range from 0.3220 to 0.6440 g/cc, those of 27.5 and 30.0 wt.% NaCl are less than 0.6782 and 0.7092 g/cc, respectively. Empirical equations have been fit to plots of critical T, P and density in order to provide estimations of critical properties for compositions intermediate to those examined. (Author's abstract)

KNIGHT, C.L. and BODNAR, R.J., 1988, Critical specific volumes and isochores of aqueous sodium chloride solutions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A152. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Fluid inclusion studies indicate that critical or near-critical density fluids occur in a variety of geologic environments. Knowledge of the critical properties of geologically applicable fluids is therefore fundamental to understanding the hydrodynamic and geochemical behavior of these systems. In many of these systems, NaCl is the dominant salt. Thus these fluids can be adequately modelled by NaCl-H_2O solutions.

Critical properties (T, P, specific volumes and isochores) of NaCl-H_2O solutions have been determined from microthermometric analyses of synthetic FI combined with an empirical equation of state for NaCl-H_2O. Critical T range from 374°C for pure H_2O to 665°C for 25 wt.% NaCl; critical T for 27.5 and 30.0 wt% NaCl are greater than 725°C. Critical P range from 220 bars (H_2O) to 930 bars (25 wt.% NaCl). Specific volumes of FI homogenizing by critical behavior were calculated using an empirical equation that re-



lates molar volume to PTX properties and is valid over the range 1-5 kbar and 100-1000°C. Critical specific volumes range from 3.11 for pure H_2O to 1.55 cc/g for 25 wt.% NaCl (see figure); those of 27.5 and 30.0 wt.% NaCl are greater than 1.47 and 1.41 cc/g, respectively. The PT trend of each critical specific volume, or isochore, was calculated for eight compositions in the NaCl-H_2O system ranging from pure water to 25 wt.% NaCl. The slopes of the critical isochores, dP/dT, increase from ~ 2.8 bars/°C for pure H_2O to ~ 6.1 bars/°C for 25 wt.% NaCl (see figure). (Authors' abstract)

KNYAZEVA, S.N., KONEVCHUK, V.G., KRIGMAN, L.V., KORSAKOVA, N.V., KOKINA, T.A., KHOTEEV, A.D. and SUSHCHEVSKAYA, T.M., 1988, An estimate of the composition of the pre-ore fluids of the Komsomolsk tin-ore region, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 191-197 (in Russian).

KOGARKO, L.N. and ROMANCHEV, B.P., 1986, A geochemical criterion for the metalliferous nature of alkali magmas: Geokhimiya, no. 10, 1986, p. 1423-1430 (in Russian; translated in Geochem. Int'l., v. 24, no. 5, p. 41-48, 1987). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Abstract in Fluid Inclusion Research, v. 19, p. 221-222. (E.R.)

KOHLSTEDT, D.L. and MACKWELL, S.J., 1988, Hydrolytic weakening of olivine (abst.): EOS, v.69, p.477.

KOHN, S.C., DUPREE, R. and FARNAN, I., 1988, Volatiles in silicate glasses: A magic angle spinning NMR study (abst.): Terra cognita, v. 8, p. 66-69.

KOIVULA, J.I., 1988, Remarkable dissolution in diamond: Z. Dt. Gemmol. Ges., v. 36, no. 3/4, p. 149-152. Author at G.I.A., Santa Monica, CA, USA.

A natural diamond crystal section containing a negative crystal cavity open to the surface was studied. A small loose diamond was found trapped within the cavity. The inner walls of the cavity and the trapped diamond crystal were both covered with brownish-green radiation stains. No such stains were observed on the host diamond's surface. (Author's abstract)

KOLPAKOVA, N.N., KOZERENKO, S.V., BARANOVA, N.N., RYZHENKO, B.N., DAR'INA, T.G., SAVEL'EVA, N.I., KOLOTOV, V.P. and GORYACHEV, N.A., 1988, Concentrations of gold, antimony, and sulfide sulfur in hydrothermal solutions and the conditions of formation of gold-ore deposits, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 122-130 (in Russian).

KOMOR, S.C., VALLEY, J.W. and BROWN, P.E., 1988, Fluid-inclusion evidence for impact heating at the Siljan Ring, Sweden: Geology, v. 16, p. 711-715. Authors at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706.

The Siljan Ring in central Sweden is a Devonian impact crater of the complex type. The ~52-km-wide crater occurs in Precambrian Dala series granites (1.65 Ga). Deep drilling in the crater provides samples from depths down to 6000 m; these are supplemented by surface samples from the crater and surrounding regions. Secondary fluid inclusions occur in matrix quartz of nearly all granites examined. Most inclusions contain low-salinity water (0-2 wt% NaCl eq.) and water vapor; no CH_4 or H_2 has been detected. In surface samples, peak Tt are 327-342°C on the crater's inner plateau, and minimum Tt are 135-225°C near the annular moat. In the subsurface, Tt distinguish two sample populations separated by a flat-lying 60-m-thick dolerite at 1200 m below sea level (-1200 m). In the deep sample group below -1200 m, estimated Tt increase with depth along gradients between 17 and 32°C/km, from ~250-300°C just below the dolerite to ~320-440°C at -5711 m. Tt samples above -1200 m are hotter than would be predicted by extrapolation of the deep trends and are believed to reflect hydrothermal activity generated by impact heating. This interpretation is supported by the presence of hotter T of fluid inclusion trapping in samples from inside the crater compared to outside, and by crosscutting relations which show that some fluid inclusion trails postdate impact related features such as planar elements in quartz. Impact-heated fluids circulated through a circular domain of rock approximately 52 km wide and at least 1.2 km thick. The large scale of this circulation system indicates that impact-generated hydrothermal activity can be a significant mechanism for heat dissipation following bolide impacts on water-bearing planets. (Authors' abstract)

KOMOR, S.C., VALLEY, J.W., BROWN, P.E. and COLLINI, B., 1988, Fluid inclusions in granite from the Siljan Ring impact structure and surrounding regions, in Deep drilling in crystalline bedrock, Vol. 1: The deep gas drilling in the Siljan impact structure, Sweden and astroblemes, A. Boden and K.G. Eriksson, eds.: Springer-Verlag, Berlin, p. 180-208. First author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706, USA.

Meteorite impacts impart large amounts of energy to target rocks. T and P distributions in impact craters can be mapped based on the distribution of melted and shocked rocks. Tt of fluid inclusions may record evidence for a thermal aureole generated by the impact. The Siljan Ring structure is a meteorite impact crater formed in late Devonian time (362 Ma). Recent drilling in the granitic basement that forms the crater floor has made available samples from depths to 6000 m. These samples, supplemented by surface samples from inside and outside the crater, make possible three-dimensional studies of impact crater characteristics. This report documents the occurrence of fluid inclusions in granites from the Siljan Ring and adjoining regions. Tt of fluid inclusions from shallow depths within the impact crater provide evidence for an impact-generated thermal aureole. The dimensions of the impact-generated aureole are large, extending to depths of more than 1 km in basement, and to the edge of the 45-km-wide crater. Outside the crater and at depths below the impact-generated aureole, fluid inclusion Tt appear to show evidence for hydrothermal activity related to Precambrian granitic plutonism. (From the authors' abstract by E.R.)

KOMOR, S.C., VALLEY, J.W. and HÉBERT, Réjean, 1988, Fluid effects in the metamorphic aureole under the Thetford Mines ophiolite, Quebec (abst.): GAC/MAC Program with Abstracts, v.13, p.A68. First author at Dept. of Geol. and Geoph., Univ. of Wisconsin, Madison, WI 53706.

Samples from the metamorphic aureole beneath the Thetford Mines ophiolite at Belmina Ridge were studied to evaluate the role of fluids in forming the aureole. Investigated lithologies include clinopyroxene-bearing garnet-amphibolite, garnet-amphibolite, epidote-amphibolite and greenschist. Two-phase aqueous fluid inclusions (vapor bubble and liquid; 3-8 microns diameter) occur in metamorphic quartz throughout the aureole. Fluid salinities are <0.1 wt.%. $NaCl_{eq}$ in most inclusions, with a few up to 1.9 wt.%. Th (vapor to liquid) range from 75 to 200°C (n=93; average=130°C, sigma=26°C). Whole-rock oxygen isotopic values for 6 amphibolites are $\delta^{18}O$ (SMOW)=10.4-14.5. Three greenschists have $\delta^{18}O$=11.3-14.5. An amphibolite from the metamorphic aureole under the

Bay of Islands ophiolite has $\delta^{18}O$=9.6. Major and trace element characteristics indicate that protoliths for aureole amphibolites are gabbros from the ophiolitic crustal section, and protoliths for greenschists are basalts. Fresh gabbros and basalts have $\delta^{18}O$ near +6, but high T ridge crest hydrothermal metamorphism causes shifts to 0 to +6 in many abyssal and ophiolitic gabbros, while lower T alteration and seafloor weathering results in values of +6 to +12 in pillow basalts. Compared to these values, the aureole amphibolites and greenschists are enriched in $\delta^{18}O$. Preliminary modeling suggest that this enrichment may have occurred through fluid interaction at low T (<300°C), consistent with fluid inclusion results. Low T fluid interaction might occur during the later stages of ophiolite obduction. (Authors' abstract)

KONNERUP-MADSEN, J., 1988, Abiogenic hydrocarbon gases associated with alkaline igneous activity: Geol. Soc. India Memoir 11, p. 13-24. Author at Inst. Petrol., Univ. Copenhagen, DK-1350 Copenhagen K, Denmark.

Fluid inclusions in minerals from agpaitic nepheline syenites and hydrothermal veins in the alkaline Ilimaussaq complex, south Greenland, and in similar agpaitic nepheline syenite complexes on the Kola Peninsula, USSR, are dominated by hydrocarbon gases (predominantly methane) and hydrogen, and contain only insignificant amounts of CO_2 and/or CO. Such volatile compositions differ considerably from those of most other igneous rock types. The formation of hydrocarbon gases in agpaitic nepheline syenites reflects the fulfillment of three basic conditions: (1) low oxygen fugacities, (2) a wide range of crystallization and a low-T solidus, and (3) retention of volatiles during crystallization.

However, calculations suggest that the hydrocarbon-rich compositions observed in fluid inclusions only represent about 5-10 mole% of the bulk fluid phase, the remaining 95-90 mole% being water. The light stable isotope composition of the hydrocarbon gases suggests an abiogenic origin of the hydrocarbons in agpaitic igneous complexes. (Author's abstract)

KONNERUP-MADSEN, Jens and DYPVIK, Henning, 1988, Fluid inclusions and quartz cementation in Jurassic sandstones from Haltenbanken, offshore mid-Norway: Bull. Minéral., v. 111, p. 401-411. First author at Inst. Petrology, Univ. Copenhagen, Østervoldgade 10, DK-1350 Copenhagen, Denmark.

Fluid inclusions have been examined in quartz overgrowth from the Middle-Lower Jurassic sandstones of the Haltenbanken area, offshore mid-Norway, in order to determine the chemical composition and T of fluids associated with quartz cementation, which appears to be late diagenetic and closely related to stylolitization. The examined fluid inclusions occur within the quartz overgrowths and along the "dust rims" of detrital quartz grains; they contain essentially aqueous solutions with salinities of 3-4 eq. wt.% NaCl and densities of 0.96-0.97 g/cm^3. Traces of hydrocarbon, presumably mainly methane, are present in some inclusions. The data indicate that quartz overgrowth occurred at a late stage in the diagenetic history, during the circulation of low-salinity aqueous fluids at T of +140°C to +170°C and at depths of burial of 3500-4500 m. Considering the burial history these conditions can only have been attained during the Late Tertiary. An average geothermal gradient of about 40°C/km is suggested by the fluid inclusion data. (Authors' abstract)

KONNERUP-MADSEN, Jens, KREULEN, Rob and ROSE-HANSEN, John, 1988, Stable isotope characteristics of hydrocarbon gases in the alkaline Ilímaussaq complex, south Greenland: Bull. Minéral., v. 111, p. 567-576. First author at Inst. Petrol., Københavns Univ., Øster Voldgade 10, DK-1350 Copenhagen, Denmark.

Fluid inclusions in minerals from agpaitic nepheline syenites and hydrothermal veins in the alkaline Ilímaussaq complex (south Greenland) are rich in hydrocarbon gases (predominantly methane), reflecting very low oxygen fugacity conditions during and after crystallization. In addition, small amounts of solid bituminous matter occur disseminated in the rocks.

Analyses of the $\delta^{13}C$ and δD compositions of methane from fluid inclusions are presented. The $\delta^{13}C$ of methane ranges from -1.0 to -5.1‰ PDB and a pronounced trend toward isotopically lighter values is observed with increased magmatic differentiation of the complex. The δD of methane ranges from -139 to -144‰ SMOW, whereas the $\delta^{13}C$ of higher hydrocarbons, extracted together with the fluid inclusion methane, is invariably higher and scatters more than $\delta^{13}C$ values of methane for the same sample. The observed differences between methane and other hydrocarbons indicate isotopic disequilibrium between the different hydrocarbon gas species, and it is suggested that some of the hydrocarbons are derived from condensed organic compounds in the rock.

The stable isotope results do not permit any definite conclusions regarding the ultimate origin of the carbon in the hydrocarbon gases. A juvenile origin is considered most plausible, although assimilation of (sodium-rich?) sedimentary or metamorphic carbonates, in conjunction with condensation to form the higher hydrocarbons and the bituminous materials upon cooling, is also a possibility. The δD compositions of the methane could indicate equilibration with magmatic water. (Authors' abstract)

KONTAK, D.J., CHATTERJEE, A.K., TAYLOR, R.P., and RICHARDSON, J., 1988, The East Kemptville topaz granite and associated Sn-base metal mineralization, southwestern Nova Scotia (abst.): GAC/MAC Program with Abstracts, v.13, p.A68. First author at Nova Scotia Dept. of Mines and Energy, P.O. Box 1087, Halifax, Nova Scotia B3J 2X1.

The East Kemptville Sn-base metal deposit (+56 million tons, 0.165 % Sn) is hosted by a qtz-albite-kf-ms-topaz-apatite leucogranite with affinities with other specialized felsic suites (e.g. ongonites). $\delta^{18}O$ (9.5‰), $\delta^{34}S$ (2-3‰) and Sr_i (0.727) also distinguish it in part from other granites in the Meguma Terrane. Tin mineralization is generally confined to discrete, chemically/mineralogically zoned topaz greisens while base metals occur in quartz veins with little associated alteration. Fluid inclusion studies indicate Th of 280±20°C for fluorite and 150-200°C for a late clay overprint. Salinities are low and CO_2-CH_4 is present in small quantities. $\delta^{34}S$ for all sulfides are similar at 5±1‰. All features indicate East Kemptville is, at present, unique in the Meguma Terrane, representing an excellent example of a chemically specialized lithophile element system. (From the authors' abstract)

KONTAK, D.J. and CLARK, A.H., 1988, Exploration criteria for tin and tungsten mineralization in the Cordillera Oriental of southeastern Peru, _in_ Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 157-169. First author at Nova Scotia Dept. Mines & Energy, Canada.

Tin and tungsten mineralization in the Cordillera de Carabaya region of southeastern Peru, representing the northernmost limit of the Central Andean tin belt, is related to crust-derived, felsic magmatism of metaluminous to strongly peraluminous composition. A "pervasive" alkali metasomatism predated the main mineralization stage, and is readily recognized in granitic rocks by: the development of "pseudo-rapakivi" alkali feldspar textures; the turbidity of feldspars; the presence of abundant, large ($\leq$ 50 μm, hypersaline, secondary, fluid inclusions in quartz phenocrysts; and the occurrence of chlorite, schorl and, rarely, cassiterite in altered granitoid rocks. The occurrence in the area of two unusually rich centers, viz the 25 Ma-old San Rafael Sn-Cu lode system, containing +2 millon tonnes of +2.5% Sn, and the ca. 8 Ma-old Palca XI tungsten vein-breccia complex, with +1.761 million tonnes of ore grading 1.2% WO_3, suggests that the mid- and Upper Tertiary monzogranitic suites offer the greatest potential for lithophile metal exploration. (From the authors' abstract by H.E.B.)

KORAGO, A.A. and APLONOV, V.S., 1987, Composition of water extracts from polar Ural quartz: Geokhimiya, no. 5, 1987, p. 685-692 (in Russian; translated in Geochem. Int'l., v. 24, no. 12, p. 68-75, 1988). Authors at Severkvarts-samotsvety Northern Prod. Coop. & All-Union World Ocean Geol. & Min. Resources Res. Inst., Leningrad, USSR.

Composition measurements have been made on 59 water extracts from vein quartz specimens of various origins and from various rocks; similarities and differences occur. The chloride and sodium levels fall from the older stages to the younger ones, while the proportions of bicarbonate, calcium, and magnesium increase. (Authors' abstract)

KORIN, E.J. and ROY, A.S., 1988, Heterogeneous equilibrium in quinary system $NaCl-KCl-MgCl_2-CaCl_2-H_2O$ in the 0-50°C temperature range: J. Chem. Eng. Data, v. 33, p. 60-64. Authors at Dept. Chem. Engrg., Ben Gurion Univ. of Negev, P.O.B. 653, Beer-Sheva 84105, Israel.

The quinary system $NaCl-KCl-MgCl_2-CaCl_2-H_2O$ was experimentally investigated in the 0-50°C T range in a condition of equilibrium with three solid phases: sodium chloride (NaCl), carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), and bischofite ($MgCl_2 \cdot 6H_2O$). A correlation was established between magnesium chloride concentration and the two independent variables, i.e., T and calcium chloride concentration. The solubilities of sodium chloride and potassium chloride were found to be low, less than 0.6 wt % NaCl and less than 0.4 wt % KCl. (Authors' abstract)

KORMUSHIN, V.A., 1978, On the metrology of the method of homogenization of gas-liquid inclusions: Alma-Ata, KAZIMS (Kazakhstan Inst. of Mineral Resources), 58 pp. (in Russian). 400 copies printed; price 52 kopecks.

A review of the mechanical aspects of heating stage construction, operation, calibration, etc. This material is also included in a later book (1982, see next item) (E.R.)

KORMUSHIN, V.A., 1981, Methods of studying fluid inclusions in minerals. Alma-Ata: "Nauka" KazSSR, 153 pp. (in Russian; translation by S. Jaireth).

The book contains new methods of thermobarogeochemistry, the theoretical basis of thermo-vacuum methods is described, instrumentation and techniques of studying fluid inclusions in vacuum are explained, methods of estimating volumetric proportions of phases, concentration of liquid phase and analysis of the composition of gaseous phase are discussed, and instrumentation and attachments for studying very small inclusions under the microscope between -195 and 600°C are described. The possibility of determining absolute age of ore formation using fluid inclusions is evaluated. The book is aimed for geochemists, mineralogists and geologists studying endogenous ore formation. (Author's abstract)

CONTENTS

KORMUSHIN, V.A., 1982, Method of homogenization of gas-liquid inclusions in minerals: Alma-Ata, "Nauka" Pub. House, 72 pp. (in Russian). 1500 copies; price 70 kopecks.

The methods of homogenization of gas-liquid inclusions in minerals are considered, including the basic principles, special devices for measurement of Th, methods of studying inclusions, and sample preparation. Recommendations are made for measuring Th in different genetic types, and for the metrology [quantification?] of the method. The book is useful for practical geological exploration. (Author's abstract)

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(Translated by T.M. Sushchevskaya)

KORMUSHIN, V.A., 1988a, Present-day state and aims of applied thermobarogeochemistry: Applied thermobarogeochemistry - Materials of the interdisciplinary seminar, June 2-4, 1987, Kazakh Acad. Sci., Alma-Ata, "Nauka" Pub. House, Alma-Ata, v. 1, p. 5-16 (in Russian). Author at the Geol. Sci. Inst. of Kazakh Acad. Sci., Alma-Ata, Kazakh SSR.

The author characterizes briefly the theoretical basis of thermobarogeochemistry and its methods. As the main methods he includes mineral-thermometric analysis, decrepitation, gas analysis of fluid inclusions, and analysis of water leachates. A table lists the parameters important for ore prospecting and obtainable by fluid inclusion studies: Th, P and phase state of mineral-forming solutions first used by Ermakov, Kalyuzhnyi and Piznyur; solution concentration (cryometry) - Kormushin, Mel'nikov; Td - Dolgov and Raykher; gasometric decrepitation - Kormushin, Dolgov; water leachate method - Moskalyuk; gas chromatography of inclusions - Mironova, Naumov and Frolov. Includes description of microscope heating stages (Ermakov's and Dolgov's models), and decrepitometers (only types listed, no technical data). The author concludes that "thermobarogeochemistry has a huge scientific potential for use in production." The author makes recommendations for use of the fluid inclusion methods in ore-prospecting and geological mapping. Probably as an example the author publishes a "model of interrelation between the zone of fluid activity and geochemical halo and ore mineralization." (Abstract by A.K.)

KORMUSHIN, V.A., (editor), 1988b, Applied thermobarogeochemistry - Materials of the interdisciplinary seminar, June 2-4, 1987, Alma-Ata, "Nauka" Publ. House, Alma-Ata 1988, v. 1 (180 pp.) and v. 2 (100 pp.), 500 copies printed, price 2 Rbl (in Russian).

The book consists of numerous short articles addressed to those who are interested in the "practical use of fluid inclusion studies," i.e., in fact to geologists who would like to use fluid inclusion methods in ore deposit prospecting. Some individual articles from this book are abstracted under the author's name, and arranged alphabetically in this volume; the bulk will be found in the next volume. (A.K.)

KORZHINSKAYA, V.S. and IVANOV, I.P., 1988, Experimental study of incongruent solubility of zircon in the system ZrO_2-SiO_2-H_2O-HCl at T 400-600°C and P 1 kbar: Dokl. Akad. Nauk SSSR, v. 299, no. 4, p. 970-973 (in Russian). Authors at Inst. Experimental Mineralogy of Acad. Sci., Chernogolovka near Moscow, USSR.

The paper presents plots of solubility of Zr in water solutions of HCl at 400, 500, and 600°C, 1 kb, fO_2 controlled by buffers Fe_3O_4-Fe_2O_3, Ni-NiO and Co-CoO, and the stability fields of quartz and zircon in the above system. (A.K.)

KORZHINSKII, M.A. and SHMULOVICH, K.I., 1988, Mineral equilibria in chloride hydrothermal solutions (abst.): Terra cognita, v. 8, p. 69. Authors at Inst. Exper. Min., USSR Acad. Sci., 142432 Chernogolovka, USSR.

The 1) Di + $CaCl_2$ = 2Wol + $MgCl_2$; 2) 7Di + 2Q + $2H_2O$ + $3MgCl_2$ = 2Trem + 3 $CaCl_2$; 3) Fa + Q + $CaCl_2$ = Ged + $FeCl_2$ mineral equilibria have been investigated using combined fO_2 and fHCl buffers technique in $MeCl_2$ solutions with the NaCl supporting electrolyte (up to 4 m) and with CO_2 up to XCO_2 = 0.2. Reaction (1) allows one to obtain $CaCl_2$ equilibrium concentrations nearly 10^2 to 10^3 as high as that of $MgCl_2$. The difference decreases with the T increasing. Reaction (3) gives the commensurable $FeCl_2$ and $CaCl_2$ concentrations. The addition of CO_2 (reactions 2,3) at $mCaCl_2$ = const increases $FeCl_2$ and $MgCl_2$ molal equilibrium concentrations by 0.5 logarithmic units. The supporting electrolyte (4 m NaCl) increases $FeCl_2$ concentrations to the same extent as 20 mol% CO_2, but it decreases $MgCl_2$ concentrations with the same magnitude. The combined addition of NaCl (1 m) and CO_2 (10 mol%) to the association (3) increases additively the $[FeCl_2]/[CaCl_2]$ ratio. The addition of $CaCl_2$ to H_2O-CO_2 solution, coexisting with Cc-Wol-An-Gross association, leads to the decrease of CO_2 concentration. The effect is noticeable even at concentrations of $CaCl_2$ = 0.05 m, which is in good agreement with the fluid phase equilibria data and other mineral reactions. (Authors' abstract)

KORZHINSKIY, A.F., KOVALISHIN, Z.I. and PLATONOVA, E.L., 1988, Physicochemical conditions of formation of the Dzhida molybdenum-tungsten deposit, as indicated by fluid inclusions: Zap. Vses. Mineral. Obshch., 1988, Pt. 117, no. 4, p. 422-428 (in Russian; translated in Int'l. Geol. Review, v. 30, p. 803-808). Authors at Inst. Geol. & Geochem. of Fuels [IGiGGI] of Ukrainian Acad. Sci., Kiev.

The content of chlorine and SO_4 ions in aqueous extracts from ore minerals of the Dzhida deposit is closely related to the CO_2 content in gas extracts. Inclusions in quartz, fluorite and accessory beryl show that the huebnerite was deposited at 290-270°C and 65 MPa at pH 8.2-8.3, whereas molybdenite, which is confined to the apical part of the stock, was deposited at 240-220°C, 40 MPa and pH 5.4. Cl^{-1} and SO_4^{-2} anions predominated in the liquid phase and CO_2 in the gas. The spatial separation of the huebnerite and molybdenite mineralization was influenced by the wall-rock composition - high Fe and Mn content in the quartz diorite and metasedimentary rocks promoted deposition of huebnerite and low, of molybdenite. (Authors' abstract)

Includes five analyses for gases (CO_2, H_2, CH_4, N_2) and three of leachates (quartz and fluorite) for Na, K, Li, Ca, Mg, Mn, Fe, Al, all from the Kholtason deposit, and two of gases and two of leachates (quartz and beryl) for the Pervomayskoyo deposit. (E.R.)

KOSTYRKO, A.A., NAUMOV, V.B. and PETROV, V.P., 1988, Peculiarities of the fluid regime of metamorphism of the Precambrian formations of the Kola Peninsula, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 93-97 (in Russian).

KOSTYUK, V.P., BAZAROVA, T.Yu., PANINA, L.I. and VAVILOV, M.A., 1986, About differentiation of alkaline basaltoid magmas and possible formation of high potassic natural melts: Geol. & Geophysics, 1986, no. 2, p. 79-85 (in Russian; English abstract).

The paper deals with alkaline potassic basaltoids, their geologic-tectonic setting; crystallization conditions based on study of melt inclusions; and the chemical composition of original basalt melts and the products of their differentiation.

The results of the research indicate possible formation of high potassic melts enriched by SiO_2 and Al_2O_3 in the course of crystallization differentiation under closed system conditions. Such conditions rarely occur in nature, thus explaining the limited range of ultrapotassic rocks of synnyrites type. (Authors' abstract)

KOSZTOLANYI, Charles, ELOY, J.-F. and BERTRAND, J.-M., 1986, The chemical heterogeneity of zircons from the Anfeg granite (Algeria) investigated by microanalytical techniques: Bull. Min., v. 109, p. 265-274 (in French). First author at Centre Recherches Géol. de l'Uranium (C.R.E.G.U.), B.P. 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Zircons from the Anfeg granite (Algeria) were investigated by electron and Raman microprobe techniques and by laser probe mass spectrometry. The latter method enables the analysis of 200-300 Å depth layers.

The analytical results show that the composition of the zircon grains is heterogeneous. In addition, the element distributions vary greatly from rims to cores, and certain elements have migrated in the crystal cores. Raman spectroscopy confirms the presence of $(OH)^-$. (From the authors' abstract by E.R.)

See also Fluid Inclusion Research, v. 20, p. 206-207, under "Kostölanyi" et al. (E.R.)

KOTEL'NIKOV, A.R. and KOTEL'NIKOVA, Z.A., 1988, Fluid inclusions in scapolites, synthesized at 600-800°C and 200 MPa in saline water-CO_2 solutions, <u>in</u> V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 85-90 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 218. (E.R.)

KOTEL'NIKOVA, Z.A. and KOTEL'NIKOV, A.R., 1988, Experimental study of fluid inclusions in minerals: Geokhimiya, 1988, no. 8, p. 1075-1083 (in Russian; English abstract). Authors at Inst. Litosf., Moscow, USSR.

In experiments at T = 400-800°C, P = 1-4.6 kbar the fluid inclusions (system silicate + water + salt ± carbon dioxide) in quartz, scapolite, wollastonite were synthesized. On the example of systems H_2O-NaCl and H_2O-NaCl-KCl an adequacy of capture of homogeneous fluid by inclusion was shown. Phase composition of the fluid is fixed in the formation of inclusions of various types. On the example of several water-salt systems, the fluid inclusions were used for estimation of phase relations. (Authors' abstract)

KOTOV, E.I., TIMOFEEV, A.V., MEL'NIKOV, I.V. and KRYLOVA, T.L., 1987, Temperature conditions for the formation of hydrothermal uranium oxides during different epochs of ore mineralization: Izv. Akad. Nauk SSSR, Ser. Geol, 1987, no. 11, p. 115-24 (in Russian). Authors at IGEM, Moscow, USSR.

Based on the determinations of the Th and Td of gas-liquid inclusions in minerals (quartz, calcite, fluorite, barite, etc.), the thermobarogeochemical conditions were estimated of mesozonal U ore deposits localized in rocks of various ages. The Td of uraninite (120-210-°) and of fluid inclusions in paragenetically associated calcite (112-246°) was determined. The samples were obtained from (1) uraninite-molybdenite deposits in Caledonian rocks, (2) Hercynian uraninite-sulfide-calcite deposits, (3) uraninite-carbonate ores formed during the Mesozoic, and (4) uraninite-marcasite-calcite ores of Late Alpine rocks. In all the deposits, hydrothermal processes initiated metasomatism of country rocks. With decreasing deposit age, the U oxides were formed at lower T: 450° in Karelian to 150° in Alpine ores. (C.A. 109: 58389u)

KOTOV, E.I., TIMOFEEV, A.V., MEL'NIKOV, I.V. and KRYLOVA, T.L., 1988, Temperature conditions of formation of hydrothermal oxides of uranium during different epochs of ore formation, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 202-210 (in Russian). See previous item.

KOTOV, Ye.I. and SKENDEROV, G.M., 1988, Hydrothermal biotite veins: Izv. AN SSSR, Ser. Geologicheskaya, 1988, no. 10, p. 36-45 (in Russian; translated in Int'l. Geol. Review, v. 30, no. 10, p. 1104-1113). Authors at Inst. Geol. Ore Deposits, Petrog., Mineral. & Geochem. [IGEM] of USSR Acad. Sci., Moscow, USSR.

The vein biotite of the Ustrem-Lesovo deposits in the Sakar ore district of Bulgaria was deposited in open fractures at the Jurassic-Cretaceous boundary. It belongs to the phlogopite-annite series and is chemically different from the biotite in the host rocks. It was deposited from deep-seated aqueous hydrothermal solutions at a T of at least 300° and P of 0.3-1 kbar. These solutions had high concentrations of CO_2, Ca and Mg and were reducing and moderately acid. These veins are widespread and can be used as a geochronological marker. (Authors' abstract)

P and S inclusions, ≤ 10 μm long, containing aqueous solution, CO_2 liquid and CO_2 vapor are reported, with ratios [volume?] of 1:2:1, respectively. Td (250-280°) < Th. Six analyses of gases (300-500°C interval) are given for H_2O, CO_2, CH_4, H_2 and N_2. Leachates showed HCO_3, F and Cl, Ca, Mg, K and Na. (E.R.)

KOTZER, T.G., REES, M.I., and KYSER, T.K., 1988, Fluids in the Athabasca basin, (abst.): GAC/MAC Program with Abstracts, v.13, p.A69. Authors at Dept. of Geol. Sci., Univ. of Saskatchewan, Saskatoon, S7N 0W0.

The Athabasca basin in northern Saskatchewan is a large Proterozoic sedimentary basin that hosts several unconformity-type U deposits. Oxygen and hydrogen isotopic compositions of chlorite and illite, occurring with U mineralization within the basement geneisses and the overlying sandstones at Key Lake, indicate that the chlorite formed from a 200°C basement fluid having δD and $\delta^{18}O$ values distinct from the basinal fluids which produced most of the illite. Illites occurring near the U have K-Ar ages of 1200 to 400 Ma that correlate directly with decreasing δD values due to interaction with late, low-T fluids (ca.50°C) having isotopic compositions comparable to modern-day Athabasca basin water. Fluid inclusions in euhedral quartz and diagenetic sandstone overgrowths from Key Lake have Th 140 to 220°C and have 10 to 32 wt.% NaCl which are similar to the high T fluids that affected the 1200 Ma diagenetic illites. Late-stage siderites with remobilized U near Key Lake have low T, low-salinity fluid inclusions that are representative of the low-T meteoric waters which entered the Athabasca basin at about 400 Ma. At Uranium City, CO_2-rich fluid inclusions in 1700 Ma gold-bearing quartz veins have Th 250-320°C and low salinities which are similar to those measured in altered Archean quartzites near Key Lake. 1200 Ma U-bearing euhedral quartz and calcite veins from Uranium City, have fluid inclusions similar to euhedral quartz in Athabasca sandstones near Key Lake suggesting that the fluids which formed and affected the Au and U bearing veins in the Uranium City area may be related to the same event that produced the fluids associated with U deposits throughout the basin. (Authors' abstract)

KOVALENKER, V.A., NAUMOV, V.B. and PROKOFIEV, V.Yu., 1988, Mineralogical and geochemical controls and PT-parameters of formation of productive associations in Kochbulaks ore field: Geol. Rud. Mesto., 1988, no. 1, p. 38-xy (in Russian).

Mineralogical and geochemical controls and PT-parameters of ore formation in Kochbulaks ore field have been investigated. Two stages of productive ore formation have been delineated. It is demonstrated that boiling and mixing of ore fluids were the principal mechanisms of ore deposition. A conceptual model of ore-forming process has been developed. (Authors' abstract, translated by S. Jaireth)

KOVALENKO, N.I., DOROFEYEVA, V.A. and VELYUKHANOVA, T.K., 1988, The thermodynamic properties of the species Sn(II) in supercritical acid fluoride fluids (abst.): Terra cognita, v. 8, p. 184-185. Authors at Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

The state of tin in the acid fluoride solutions at 500°C, 1 kb and in the presence of Ni-NiO buffer was studied using the solubility method. The main equilibrium for the solubility of cassiterite in the interval of the HF from 0.05 to 0.75 m is the following: (1) $SnO_{2(c)} + H_{2(g)} + 2HF^\circ = SnF^\circ_2 + 2H_2O$. Thermodynamic analysis shows that in the concentration range 0.01 to 0.07 m of HF and from 0.005 to 0.05 m of NaF (pH = 4.8 - 5.65) $SnF_2(OH)^-$ is the major tin species, according to the reaction: (2) $SnO_{2(c)} + H_{2(g)} + 2H^\circ = SnF_2(OH)^{+}H^{+} + H_2O$ and in the interval from 0.1 to 0.75 m of HF and 0.01 to 0.1 m of NaF (pH = 4.0 - 5.05) two tin species can predominate: $SnF_2(OH)^-$ and SnF_3^-, the latter according to the equilibrium: (3) $SnO_{2(c)} + H_{2(g)} + HF^\circ = SnF_3^- + H^+ + 2H_2O$.

The constants of equilibrium of the reactions and values of standard free energy of formation of these complexes at 500°C were calculated. T dependence of the equilibria (1) and (3) are constants between the interval 5 to 500°C and H° and S° values of the reactions (1) and (3) were calculated from the experimental results combined with literature data (for 25°C). Problem of the origin of tin deposits connected with Li-F granites are discussed. (Authors' abstract)

KOVALENKO, N.I., RYZHENKO, B.N., VELYUKHANOVA, T.K. and BARSUKOV, V.L., 1986, Cassiterite solubility in HF solutions and forms of tin transport by supercritical fluids: Dokl. Akad. Nauk SSSR, 1986, no. 290, no. 1, p. 211-214 (in Russian; translated in Dokl. USSR Acad. Sci., Earth Sci. Sects., v. 290, p. 212-215, 1988).

KOVALENKO, V.I., HERVIG, R.L. and SHERIDAN, M.F., 1988, Ion-microprobe analyses of trace elements in anorthoclase, hedenbergite, aenigmatite, quartz, apatite, and glass in pantellerite: Evidence for high water contents in pantellerite melt: Am. Mineralogist, v. 73, p. 1038-1045. First author at Inst. Geol. of Ore Deposits, Petrogr., Min. & Geochem., USSR Acad. Sci., Moscow 109017, USSR.

Ion-microprobe analyses of matrix glass and glass inclusions in anorthoclase and quartz phenocrysts in pantellerite show no major differences in chemistry except for H_2O (4.3 ± 0.2 vs. 0.5 ± 0.1 wt%) and Cl (1.3 vs. 0.9 wt%), which degassed from the matrix during the process of eruption. This high measured water content contrasts with current assumptions that pantellerites are relatively dry magmas. Comparison of secondary-ion intensities from glass and phenocrysts of anorthoclase, hedenbergite, aenigmatite, quartz, and apatite gives partition coefficients (with errors of a factor or two) that are ≤ 1 for B, P, Rb, Zr, Nb, Sn, and Cs for all silicate phenocrysts. Even if individual phase partition coefficients are >1 (Sr, Y, Ce in hedenbergite; Li in aenigmatite; Ba in anorthoclase; REE in apatite), the resulting bulk crystal/liquid partition coefficients are still <1 so that fractional crystallization of pantelleritic liquids could generate peralkaline rare-metal granites and pegmatites. (Authors' abstract)

KOVALEVICH, V.M., 1987, Phanerozoic evolution of ocean water composition: Geokhimiya, no. 11, p. 1527-1536 (in Russian; translated in Geochem. Int'l., v. 25, no. 6, p. 20-27, 1988).

KOZŁOWSKI, A. and METZ, P., 1988a, Decrepitation: Expectations, reality and limits: (Abstract distributed at Fluid Infotreffen '87 in the Inst. of Geol. & Geodynamics of Lithosphere in Göttingen, 29-30.X.1987, but not in official program. A.K.)

The mechanism of the decrepitation of fluid inclusions with various habits is briefly discussed and the relations between 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 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 the Th nor to Tt of fluid inclusions. Examples are given which indicate that the mechanical distinguishing of "inclusion generations" on a decrepigram from its peaks may be misleading and that one generation of inclusions may result in a bi- or multimodal histogram of Td versus the number of the inclusions decrepitated.

The following decrepitation techniques and devices are described: acoustic, piezoelectric, gravimetric, visual, barometric (vacuum), gasometric, photometric and radiometric (radio wavelength). An 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 the prospecting tool but not as the geothermometric method. (Authors' abstract)

KOZŁOWSKI, Andrzej and METZ, Paul, 1988b, Cr-Ti-Fe spinels in melt inclusions in olivines: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 213-224. First author at Inst. Geochem., Mineral. & Petrogr., Fac. Geol., Warsaw Univ., Al. Zwirki i Wigury 93, PL-02-089 Warszawa, Poland.

Olivine phenocrysts ($Mg_{1.6}Fe_{0.4}SiO_4$) in limburgite from the volcanic complex of Vogelsberg (FRG) contain polyphase melt inclusions with trapped and/or daughter spinels. Similar spinels with distinct compositional zoning from Cr-rich cores to Cr-poor Ti-rich rims occur also in the rock matrix. This zoning is primary and an attempt is made to combine the Cr_2O_3 content in the groundmass spinels (33 to 2 wt.%) with Th of melt inclusions in olivine phenocrysts (1360-1270°C) for indirect estimation of crystallization T of groundmass spinels. The possibility of evaluation of oxygen fugacity of the magma is also discussed. (Authors' abstract)

See also same authors, 1986, Fluid Inclusion Research, v. 19, p. 238-239. (E.R.)

KOZŁOWSKI, Andrzej, METZ, Paul and ESTRADA JARAMILLO, H.A., 1988, Emeralds from Somondoco, Colombia: Chemical composition, fluid inclusions and origin: Neues Jahrbuch Miner. Abh., v. 159, no. 1, p. 23-49.

Full paper for abstract in Fluid Inclusion Research, v. 19, p. 240, 1986. (E.R.)

KOZŁOWSKI, A., METZ, P. and WISZNIEWSKA, J., 1988, Garnet-bearing parageneses of the tin deposit in the Stara Kamienica Chain, Lower Silesia (abst.): Fortschritte der Mineral., v. 66, Beiheft 1, p. 86.

The investigated cassiterite-sulfide (arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, galena, etc.) deposit occurs in schists, which were regionally metamorphosed under the conditions of the quartz-albite-almandine subfacies of the greenschist facies. The schists, which themselves belong to the country rocks surrounding the Variscan Karkonosze (Riesengebirge) granitoid massif, consist of the following minerals: Fe-rich chlorite, biotite, Na-muscovite, chloritoid, almandine garnet (with variable admixtures of grossular and spessartine), rare albite and abundant quartz.

The deposit, initially assumed to be of hydrothermal origin, was later considered to be a stratabound metasedimentary (placer) cassiterite formation. Our new data indicate that the deposit has been formed by hydrothermal fluids. Inclusions of these fluids in quartz and hydrothermal garnet have Th of 250 to 350°C. The generation of the ore-forming fluid is probably connected with the intrusion of the Karkonosze granitoid. The activity of the hydrothermal fluid has apparently overlapped the process of regional metamorphism, as can be seen from the garnet zoning and from the occurrence of sulfides, ilmenite and cassiterite found within garnet crystals. A special type of garnet is characteristic for the ore oxide-bearing paragenesis (cassiterite and Zn-spinel: gahnite 76, hercynite 12 and franklinite 12) and thus may be used as a diagnostic tool for prospecting.

Ilmenite has been formerly described as a relic clastic mineral of the parent sediments of the schists. However, its pyrophanite ($MnTiO_3$) molecule content, varying from 0.0 to 1.0, has values specific for various garnets or their growth zones, which indicates equilibrium growth of garnet and ilmenite (or chlorite and ilmenite), and thus the metamorphic origin of the latter. The composition of the fluids, forming the ore and barren parageneses, will be discussed with particular respect to their fluorine/chlorine ratio. (Authors' abstract)

KOZ'MENKO, O.A., BELEVANTSEV, V.I. and PESHCHEVITSKIY, B.I., 1987, The solubility of BeO in aqueous HF at 250 and 350°C: Geokhimiya, no. 11, p. 1655-1657 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 6, p. 135-138).

KRANIDIOTIS, P. and WOOD, S.A., 1988, The solubility of $Cu-Cu_2O$ in hydrothermal chloride solutions from 150 to 250°C (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 54. Authors at Dept. Geol. Sci., McGill Univ., Montreal, PQ, H3A 2A7, Canada.

Barnes-type large volume (1.1 lit.) autoclaves were used to measure the hydrothermal solubility of the $Cu-Cu_2O$ assemblage in 1-3 m $H_2O-NaCl$ solutions from 150 to 250°C and undersaturated water vapor P. Initial pH was adjusted (pH = 4 to 5) by using HCl. The $Cu-Cu_2O$ mixture served both as the copper saturating phases and oxygen buffer. Samples were withdrawn at P and T via a valve system. The titanium liners that were initially employed to prevent corrosion of the stainless steel autoclaves and contamination of the solutions, were corroded and perforated due to the formation of electrochemical cells that locally transferred and reprecipitated Ti ions. Copper liners were subsequently used with success.

The solubility increased with T from 215 ± 6 ppm at 150°C, to 303 ± 24 ppm at 200°C and to 416 ± 40 ppm at 250°C. Increased solubilities in runs with higher chloride concentrations suggest that Cu^+ - the stable form of copper under these conditions as indicated by the colorless solution at T and thermodynamic calculations - formed a chloride complex. These results are directly applicable to some sedimentary copper deposits thought to have formed at 150 to 200°C and under similar fO_2 conditions. The experiments are being extended to 400°C and 8-9 m NaCl in order to derive Cu-chloride complexation constants applicable to massive sulfide and porphyry deposits. (Authors' abstract)

KRǍSTEVA, Margarita and STOJNOVA, Margarita, 1988, Fluid inclusions in quartz from the deposits in the Laki ore field, Central Rhodope Mts.: Geohim., mineral. i petrol., no. 24, 1988, p. 41-54 (in Russian).

The mineralizations in the Laki ore field form veins and metasomatic bodies located in marble beds at the base of the Proterozoic sequence. Fluid inclusions are homogenized on a Koffler-type thermal stage and the T is measured with a mercury thermometer the accuracy being ± 3-5°C. Mineral deposition took place in the following stages: johanssenite-rhodonite, quartz-epidote-pyrite, quartz-sphalerite-galena, dolomite-sphalerite and quartz-calcite. Th measurements are carried out on quartz (2nd generation) for the quartz-sphalerite-galena stage and on quartz (3rd generation) for the dolomite-sphalerite stage. Quartz contains abundant inclusions of non-uniform distribution ranging from 0.430/0.080 to 0.006/0.004 mm in size. Their Th in quartz 2nd generation are 370-250°C. Th of quartz from the Goranska-Padina metasomatic bodies are 10-20°C higher, whereas Th of quartz from the Govedarnika metasomatic bodies are 15-25°C lower. Th of fluid inclusions in quartz (3rd generation) are 310-190°C with the exception of the samples from the Govedarnika deposit showing Th of 330-310°C. (Abstract by S. Aslanjan)

KRAVCHUK, I.F. and MALININ, S.D., 1988, Behavior of some petrogenetic and ore elements by the interaction of fluid and silicate melts (abst.): Terra cognita, v. 8, p. 186. First authors at V.I. Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

Igneous processes - crystallization of magma or melting of the rocks - often imply the presence of separate fluid phase, so the experimental investigation "melt-fluid" equilibria is important for understanding of geochemical processes.

The constants of exchange reactions and partition coefficients of Na, K, Ca, Cl between silicate melts (natural granite, its artifical analogs, albite) and water-salt fluid have been determined at 900°C and 2 kbar. It has been found that the value of constant Na-K exchange reaction for all studied systems is invariable (1.65 ± 0.25). The obtained experimental data indicate that fluids being in the equilibrium with silicate melts should have a complex salt composition. The partition coefficient of Mo between silicate melt and 1 m solution of NaCl has been obtained close to 1 (800°C, 1.5 kbar). (Authors' abstract)

KRESTOV, G.A. and KUDRYAVTSEV. S.G., 1988, Thermodynamic characteristics of dissolution of non-polar gas in a liquid: Dokl. Akad. Nauk SSSR, v. 299, no. 2, p. 392-395 (in Russian). Authors at Inst. Chem. of Non-water Solutions of Acad. Sci. USSR, Ivanovo, USSR.

The paper presents solubility of Ne and He in water, partition coefficients between liquid and gas phase, and the standard thermodynamic characteristics of argon dissolution in organic liquids and in water. (A.K.)

KREULEN, Rob, 1988, High integrated fluid/rock ratios during metamorphism at Naxos: Evidence from carbon isotopes of calcite in schists and fluid inclusions: Contrib. Mineral. Petrol., v. 98, p. 28-32. Author at Inst. Earth Sci., Univ. Utrecht, P.O. Box 80.021, NL-3508 TA Utrecht, The Netherlands.

Calcite in schists of the metamorphic complex at Naxos is depleted both in ^{13}C and in ^{18}O with respect to massive marbles. This effect is attributed to isotope exchange with circulating CO_2-rich fluids, which had an $X(CO_2) > 0.5$ according to fluid inclusions. The carbon isotopic composition of the calcites is close to equilibrium with fluid inclusion

CO_2 at metamorphic T. Mass balance calculations assuming initial $\delta^{13}C$ values of 0 for calcite and -5 for the fluid, give integrated fluid/rock volume ratios between 0.1 and 2.0. Such high fluid/rock ratios are supported by observations on the distribution of CO_2/H_2O ratios of fluid inclusions, carbon isotopic compositions of fluid inclusion CO_2 and oxygen isotope systematics of silicates. (Author's abstract)

KRIER-SCHELLEN, A.D., 1988, Microthermometric study of fluid inclusions from various parageneses in the scheelite (tungsten) ore deposit of Salau (Pyrenees, Ariège Dept., France): PhD dissertation, Univ. Catholique de Louvain, 64 pp. (in French).

No abstract available. (E.R.)

KRUPP, R., 1988a, Solubility of stibnite, solution species and equilibrium constants from 25 to 350°C (abst.): Terra cognita, v. 8, p. 182. Author at Bayerisches Geoinstitut, Univ. Bayreuth, FRG.

The speciation of Sb in aqueous solution has been studied experimentally by a solubility technique as a function of pH, total reduced sulfur (TRS) concentration, and T.

An important change in speciation with T has been established. At high T and TRS <0.01 molal stibnite solubility is controlled over the entire pH range by the hydroxothioantimony (III) complex $Sb_2S_2(OH)_2^0$. At T below approx. 250°C two series of thiantimonite complexes occur: at TRS concentrations above approx. 0.01 molal dissociation products of $H_3SbS_3^0$ dominate while at lower TRS concentrations the $H_2Sb_2S_4^0$ series is more important.

The higher stability of the unchanged species $Sb_2S_2(OH)_2^0$ at elevated T can be related to the changing properties of water with T.

The results of this study have implications on the formation of hydrothermal ore deposits. At T below 100 to 150°C significant amounts of Sb (>1 ppm) can only be transported in sulfide-rich neutral to alkaline hydrothermal fluids while at higher T antimony transport is possible over the entire pH range, but is favored by low-sulfide fluids. (Author's abstract)

KRUPP, R.E., 1988b, Solubility of stibnite in hydrogen sulfide solutions, speciation, and equilibrium constants, from 25 to 350°C: Geochimica Cosmo. Acta, v. 52, p. 3005-3015.

See previous item. (E.R.)

KRUSTEVA, M. and STOINOVA, M., 1988, Fluid inclusions in quartz from ore deposits in the Laki field, central Rhodope Mts. [Bulgaria]: Geokhim., Mineral. Petrol., v. 24, p. 41-54 (in Bulgarian). Authors at Geol. Inst., 1113 Sofia, Bulgaria.

In the Laki field (Bulgaria), Pb-Zn ore mineralization occurs as veins and metasomatic bodies at the base of a Proterozoic sequence. Major ore minerals are galena, sphalerite, pyrite, and chalcopyrite. Quartz, calcite, dolomite, rhodonite, and johanssenite are the most common non-metallic minerals. Mineral deposition took place in 5 stages, with the paragenesis: johannsenite-rhodonite, quartz-epidote-pyrite, quartz-sphalerite-galena, dolomite-sphalerite, and quartz-calcite stages. Most quartz (Q) samples were sampled from the ore veins of the Q-sphalerite-galena (Q^2) and dolomite-sphalerite (Q^3) stages in the deposits of Goranska Padina, Dzurkovo, Pilevo, Cetroka, Govedarnika, Kenan Dere, and Momcil Junak. Both Q^2 and Q^3 contain abundant fluid inclusions distributed irregularly which is due to the specific features of Q growth. Fluid inclusions are commonly prismatic, tubular, and lenticular. Th of fluid inclusions in Q^2 are 250-370° and 250°. Higher-T inclusions are found in Q from the Pilevo, Cetroka, and Kenan Dere deposits. The Th of fluid inclusions in Q^2, from the Goranska Padina metasomatic body, are 10-20° higher than that in ore-vein Q from the corresponding horizon. The Th of fluid inclusions in Q^3 is 190-310°. (C.A. 109: 96157z)

KUL'CHETSKAYA, A.A., 1988, The use of inclusions in gypsum for resolving some problems of sedimentary mineral-formation, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 137-143 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 226. (E.R.)

KUMAR, Anil, 1988a Estimation of ion product of water in sea water: J. Chem. Eng. Data, v. 33, p. 48-49.

KUMAR, Anil, 1988b Mixture densities of aqueous KCl with NaCl up to ionic strength 4.5 mol kg^{-1} and at 298.15 K: J. Chem. Eng. Data, v. 33, p. 198-199. Author at Dept. Sugar Chem., Deccan Sugar Inst., Manjari (BK) 412 307, Poona, India.

The experimental density differences, Δd, are reported for aqueous mixtures of KCl with NaCl at 298.15 K from the constant ionic strength, I, 0.5-4.5 mol kg^{-1} of water. The results are fitted to the equations derived by Patwardhan and Kumar (equivalent to Young's rule) and by Pitzer. The interactions between Na^+ and K^+, as shown by the excess volumes, ΔV_m, are very small. (Author's abstract)

KURDYUKOV, E.B. and BERDNIKOV, N.V., 1987, Pressure-temperature conditions of metamorphism and granitization of the Sharyzhalgai Complex (southwestern Cisbaikalia) [USSR]: Izv. Akad. Nauk SSSR, Ser. Geol., 1987, no. 12, p. 42-49 (in Russian). Authors at IGEM, Moscow, USSR.

Formation conditions of rocks in the Precambrian Sharyzhalgai migmatite complex are estimated by use of various mineral geothermometers and study of fluid inclusions (FI). The FI are of three types: (1) liquified CO_2, (2) gases with a low b.p., and (3) aqueous solution. The CO_2 inclusions were dominant in the quartz (Q) and plagioclase of all samples. The basic crystallized schists and granulites formed at 700-800°, and at these temps P of 5.3-7.4 kbar were developed, according to the P inclusions. Enderbites and charnockites formed at 700-800°, 3.0-7.4 kbar. The Pt of biotite granites, calculated from CO_2 inclusions, was 1.2-5.5 kbar, at crystallization T of 700-750°. The biotite granites are Proterozoic, whereas the enderbites and charnockites are Archean; however, all of these rocks originated from the granitization of the basic crystallized schists. (C.A. 109: 58552s)

KURILO, M.V., 1988, Polymetallic mineralization in metasedimentary formations of the Ukraine (genetic types, formation conditions, and mineral typomorphism): Litologiya i Poleznye Iskopaemye, no. 5, p. 58-69 (in Russian; translated in Lithology and Mineral Resources, May 1988, p. 462-472). Author at Inst. Geochem. & Min. Physics, Acad. Sci. of Ukrainian SSR, Kiev.

Th is given for quartz, carbonate and sphalerite occurring in ore veins from the Nagol' Ridge. (H.E.B.)

KURZ, M.D., GURNEY, J.J., JENKINS, W.J. and LOTT, D.E., 1987, Helium isotope variability within single diamonds from the Orapa kimberlite pipe: Earth Planet. Sci. Lett., v. 86, p. 57-68.

KUZNETSOV, P.P. and SIMONOV, V.A., 1988, Ophiolites in rifts: Novosibirsk, Nauka Publ. House, 150 pp. (in Russian). ISBN 5-02-028813-6: 1000 copies printed; price 2 roubles, 20 kopecks. Continued next page.

Includes considerable discussion of silicate melt inclusions, to be abstracted in the next volume. (E.R.)

KUZNJETSOVA, S.V., KOMAROV,O.M. and GOSTYAJEVA,N.M., 1988, Temperature conditions of diaphthorites and alkaline metasomatic rocks of the Uman Zone, Ukrainian Shield: Dopovidi Akad. Nauk Ukrayins'koyi RSR, Ser. B: Geol., Khimichni ta Biologichni Nauki, 1988, p. 24-27 (in Ukrainian).

Indexed under "Fluid Inclusions." (E.R.)

KUZNETSOVA, S.V. and KULIK, Zh.V., 1986, Chlorine-derivative hydrocarbons in mineral-forming solutions: Dokl. Akad. Nauk SSSR, 1986, no. 290, no. 3, p. 709-710 (in Russian; translated in Dokl. USSR Acad. Sci., Earth Sci. Sects., v. 290, p. 223-224, 1988).

Translation published in Fluid Inclusion Research, v. 19, 1986, p. 511-512. (E.R.)

KUZNETSOVA, S.V., SHCHERBAK, D.N. and NIKOLAEVSKII, V.P., 1988, Fluid-explosive genesis of breccias in the Bug series rocks of the Ukrainian Shield: Dokl. Akad. Nauk Ukr. SSR, Ser. B, Geol., Khim. Biol. Nauki, 1988, no. 6, p. 14-16 (in Russian). Authors at Otd. Metallogen., Inst. Geokhim. Fiz. Miner., Kiev, USSR.

The breccia body in the Lower Proterozoic Bug series of the Ukrainian Shield (USSR) occurs along a fault in graphite gneisses and consists of blocks of quartzite, gneisses, granitic rocks, and jasper-like rocks in a cement with many newly formed minerals. Phlogopite and aeladonite [celadonite] of the cement are described; chemical compositions are given and the phlogopite yielded a K-Ar age of 1720 Myr. Argillaceous material in the breccia cement has high CO_2 concentration (411-816 mL/kg); also, fragments of altered gneiss contain Cl^- 182 x 10^{-6} g/g, F^- 39.7 x 10^{-6} g/g, and CO_2 651-4910 mL/kg. Quartz of the breccia has two types of pyrite (one containing Cu 0.2, Ni 0.1% and the other Co-rich) and many fluid inclusions (FI); the FI include those which are two-phase gas-liquid, two-liquid, multiphase with mineral phases, and CO_2-dominant FI. According to criteria given by G.J. Tugovik (1982), the breccia classifies as the fluid-explosion type. It is indicative of tectonomagmatic activation; possibly, basic magmatic activity occurred 1720 Myr ago. (C.A. 111: 10495q)

KYLE, J.R., BOARDMAN, Sabine and PRICE, P.E., 1988, Mississippi Valley-type Zn-Pb-Ag mineralization in Jurassic carbonate rocks, Smackover Formation, southwest Arkansas (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A39. First author at Dept. Geol. Sci., Univ. Texas at Austin, Austin, TX 78713.

Sulfide minerals are common in the upper part of the Smackover Formation, a Jurassic carbonate ramp sequence that is a major petroleum producer in the Gulf Coast. The study area occurs along the Arkansas Shelf on the northern flank of the North Louisiana Salt Basin within an area of Smackover petroleum production. Current formation waters are Na-Ca-Cl brines locally containing commercial Br and elevated hydrogen sulfide contents. The No. 1 Teague well in Lafayette Co., AR, contains sulfides throughout the total cored interval from 8362-8484 ft with the most intense mineralization in ooid-lime-grainstones in the upper 35 ft. Sulfides form complex replacement and pore-filling textures and are locally associated with styolites, particularly in the dense lower limestone section. There is a general correlation between Zn and Pb concentrations and present-day porosity and permeability. Minerals forming the late-stage mineral assemblage include fine-grained tan sphalerite, galena, acanthite, chalcopyrite, pyrite, marcasite, dolomite, coarse-grained yellow-brown sphalerite, and calcite. Although the Ag content of the high Zn-Pb zones is generally low (<1 to 10 ppm), a local acanthite-rich 1-ft interval assays over 1000 ppm.

FI data for coarse-grained sphalerite indicate precipitation from Na-Ca-Cl brines in a Th range of 90 to 105°C. Petroleum-filled inclusions also occur in late-stage calcite. $\delta^{34}S$ for sulfides ranges from +8.9 to +16.6‰ (CDT); Δsl-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 sea water sulfate, suggesting that thermochemical reduction of reservoir sulfate is the source of the H_2S for sulfide mineralization. Textural evidence suggests that sulfide precipitation from metalliferous brines was initiated at sites of local sulfate reduction in the upper Smackover. The presence of acanthite in the Smackover and salt dome cap rock sulfide deposits in the Gulf Coast indicates that Ag is a component of "ordinary" formation waters in sedimentary basins, a feature that should be considered with regard to origin of several types of sediment-hosted Zn-Pb-Ag deposits. (Authors' abstract)

LABOTKA, T.C., NABELEK, P.I. and PAPIKE, J.J., 1988, Fluid infiltration through the Big Horse Limestone Member in the Notch Peak contact-metamorphic aureole, Utah: Am. Mineral., v. 73, p. 1302-1324. First author at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996, USA.

Calcareous argillites have undergone contact metamorphism, resulting in nearly complete decarbonation, yet the mineral assemblages indicate that the fluid phase was nearly free of CO_2, indicating interaction with a substantial volume of water. This study is designed to determine the volume of externally derived water and the mode of interaction.

Simple calculations of the T and fluid flux through the aureole, based on heat- and fluid-transport equations, indicate that heat transport on the margins of the stock occurred primarily by conduction, particularly outside the wollastonite zone, and that the major fluid flux through the aureole occurred within the first year of intrusion, long before the T had risen sufficiently for metamorphism to have occurred. Fluid fluxes through the aureole after 1000 yr, when significant metamorphism occurred, dropped to the order of 1 kg/(m^2·yr), or less. This amount is sufficient to have interacted with the diopside-zone rocks, giving water/rock ratios (by mass) of the order 0.1. The results of this study indicate that in those metamorphic terranes in which there is a change from rock-dominated to fluid-dominated systems across an isograd, the water/rock ratio in the fluid-dominated system represents not the fluid flux, but the mass of fluid in a reservoir with which the rocks equilibrated. (From the authors' abstract by E.R.)

LABOTKA, T.C., NABELEK, P.I., PAPIKE, J.J., HOVER-GRANATH, V.C. and LAUL, J.C., 1988, Effects of contact metamorphism on the chemistry of calcareous rocks in the Big Horse Limestone Member, Notch Peak, Utah: Am. Mineral., v. 73, p. 1095-1110. First author at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996, USA.

There is no evidence for large-scale migration of major or trace elements, despite the apparent substantial infiltration of H_2O during metamorphism. (From the authors' abstract by E.R.)

LACAZETTE, Alfred and ENGELDER, Terry, 1988, An ancient pressure-seal chamber and its role in the evolution of the central Appalachian fold thrust belt (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A58.

Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

The Valley and Ridge province of Pennsylvania is thought to have formed a passive roof duplex. The Cambro-Ordovician carbonate section was imbricated while the overlying, predominantly clastic section was detached and passively folded by accommodation to the growing fault bend folds in the underlying carbonates. This detachment developed within the Ordovician Reedsville Shale. Evidence from FI in syntectonic veins, vein mineralogy, frequency and geometry of joints and veins in outcrop, and diagenetic history of the rocks indicates that the Reedsville, the overlying Bald Eagle sandstone, and possibly the underlying carbonates formed a P-seal chamber in which elevated fluid P developed prior to the onset of thrusting and persisted during at least part of the deformation.

The elevated fluid P may have been generated by a combination of maturation of hydrocarbons in the Reedsville, clay dehydration, and compaction. These fluids consisted of hydrocarbon-rich, highly saline, reducing brines. Thin shale beds within the Bald Eagle and/or an upward increase in the matrix clay content of the sandstones appear to have served as the seals that contained the pressurized fluids. The roof of the P-seal chamber was thus slightly above the detachment horizon. Deformation led to the development of fractures and breccia zones along which the brines were expelled (resulting in decreased pore P) and along which meteoric water later gained access to deep levels of the fold-thrust belt. Bedding parallel veins associated with the onset of thrusting are located above the detachment horizon. These indicate that the pore P approached lithostatic at this time. Fluid P estimates from FI in these veins thus allow an estimate of 4 km for the Alleghenian overburden.

This pore P history may be responsible for the structural style of the thrust belt. Elevated pore P in the Reedsville may have helped to decouple the passive roof from the carbonate stiff layer and may have facilitated movement along thrust faults in the carbonates. Paleomagnetic and outcrop evidence suggest that folding was substantially completed before the invasion of meteoric water and coincident pore P decline. The cessation of folding may be a result of increased internal friction within the thrust belt due to the decreased pore P. (Authors' abstract)

LAI, Yingjian, 1988, Origin of the Fankou lead-zinc deposit: Geol. Review, v. 34, no. 3, p. 220-230 (in Chinese; English summary).

Indexed under "Fluid Inclusions." (E.R.)

LAIER, T., 1988, Hydrocarbon gases in crystalline rocks at Siljan, Swedish deep gas project (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A25. Author at Geol. Survey of Denmark, Thoravej 8, DK-2400 Copenhagen, Denmark.

Two types of hydrocarbon gases were found in trace quantities in the cuttings from Gravberg-1, the Swedish deep gas well. One type associated with the dolerite sills 900 Ma was an isotopically heavy, $\delta^{13}C_1$: -11 to -15‰, dry gas, presumbly of abiogenic origin. The other type which was found throughout the granites was characterized by isotopically lighter methane, δC_1: -21 to -39‰, and higher contents of C_{2+} with C_2-C_4 olefins and paraffins in almost equal amounts.

The second type of gas was probably formed by a catalytic reaction, e.g., Fischer-Tropsch reaction, since most of the gases were associated with the magnetic fraction. Hydrocarbon analyses of cuttings by the desorbed gas method were apparently unaffected by drilling conditions suggesting that the gas was not produced artificially. Hydrocarbon analyses of cores confirmed this assumption.

The appearance of tiny accumulations of gas in polished thin sections with time and the apparent dependence of headspace gas concentrations with storage time of canned cuttings suggest that the gases in granite diffuse quite freely. The existence of two separate types of hydrocarbon gases thus suggests that the gas confined within the dolerite sills exists in inclusions.

Hydrocarbon analyses of magnetic fraction of outcrops from various areas together with occurrence of similar types of gases in other wells in crystalline rocks suggest that the granitic type of gas occurs widespread in crustal rocks. (Author's abstract)

LAL, D., CRAIG, H., CURTIS, D. and LAFFOON, M., 1988, Nuclear processes in diamonds and other mantle samples (abst.): Inst. Geophys. & Plan. Physics Ann. Report, p. 23-24.

See next item. (E.R.)

LAL, D., 1987, Production of ^{3}He in terrestrial rocks, in New Developments and Applications in Isotope Geoscience: Chem. Geol. (Isotope Geosci. Sec.), v. 66, p. 89-98. Author at Scripps Inst. Oceanography, Geol. Res. Div., A-020, La Jolla, CA 92093, USA.

I consider possible nuclear sources for in situ production of ^{3}He in rocks. The in situ cosmogenic production of ^{3}He and ^{3}H (which decays to ^{3}He with a half-life of 12.34 a) occurs due to both "cosmogenic" and radiogenic" nuclear reactions as has been discussed in the literature. The subject is in a state of flux because of new experimental data on the distribution of ^{3}He in terrestrial samples. In situ cosmogenic production of ^{3}He(^{3}H) in rocks has been documented recently. Evidence for the presence of in situ cosmogenic ^{3}He in an alluvial diamond sample has also been found. Some diamonds have been found to contain ^{3}He at concentration levels of $\sim 50 \cdot 10^{-12}$ cm^3/g diamond, and ^{3}He/^{4}He ratios of $(70\text{-}300) \cdot 10^{-6}$.

I discuss the propagation of cosmic-ray secondaries in the atmosphere and in rocks, and present estimates for the rates of nuclear disintegrations due to neutrons, fast μ-mesons and capture of negative muons up to equivalent depths underground of 10^4 g cm^{-2} (0 - ~30 m rock). For the same rock depths, I also present estimates for the production rates of sub-MeV radiogenic neutrons from granite, clays and shales and basalt. Cosmogenic spallation and thermal neutron cosmogenic and radiogenic production rates of ^{3}He can be obtained from the production rates given. (Author's abstract)

LAL, D., NISHIIZUMI, K., KLEIN, J., MIDDLETON, R. and CRAIG, H., 1987, Cosmogenic ^{10}Be in Zaire alluvial diamonds: Implications for ^{3}He contents of diamonds: Nature, v. 328, p. 139-141. First author at Scripps Inst. Oceanography, La Jolla, CA 92093, USA.

To determine the amounts of cosmic-ray produced ('cosmogenic') ^{3}He which could be created in diamonds during their post-eruptive residence in near-surface regions, we have measured the concentration of ^{10}Be (half life, 1.6 Myr) in an industrial diamond sample. The motivation to study cosmogenic ^{3}He in diamonds comes from the recent observations of ^{3}He/^{4}He ratios in some diamonds that are even higher than meteoritic values (so-called 'planetary' helium with ^{3}He/^{4}He = 1.4×10^{-4}). We measured ^{10}Be in an alluvial diamond sample, using radiochemical and accelerator mass spectrometry (AMS) techniques. The observed ^{10}Be concentration, $2.46 \pm 0.39 \times 10^6$ atoms g^{-1}, leads to an effective surface exposure 3.3×10^5 yr for these diamonds. This corresponds to a substantial cosmogenic production of ^{3}He in the alluvial diamonds, >29% of the total ^{3}He. We conclude that the high ^{3}He/^{4}He ratios in at least some diamonds are due to cosmogenic ^{3}He production in near-surface regions during their residence in alluvial or weathering deposits. Thus, in order to establish that such high ^{3}He/^{4}He ratios existed in the mantle at one time, it is a priori necessary to study diamonds collected by underground mining methods. (Authors' abstract)

Includes a discussion of some of the ^{3}He/^{4}He results of Honda et al. (1987), in Fluid Inclusion Research, v. 20, p. 175. (E.R.)

LAMB, W., 1988a Fluid inclusions in Adirondack granulites: Evidence for late entrapment, and constraints on the retrograde P-T path: Terra cognita, v. 8, p. 254-255. Author at Dept. Geol., Texas A&M Univ., USA.

Granulite-facies rocks from the Adirondack Mts., N.Y., contain a variety of fluid inclusions, including: (1) CO_2-rich, (2) mixed $H_2O + CO_2 \pm$ salt, and (3) H_2O-rich with variable salinity. These inclusions are 3 to 5 μm in diameter and occur in quartz. CO_2 Th (Th(L-V)CO_2) for those inclusions that are CO_2-rich (i.e., no visible aqueous phase) range from -45.9 to +31.0°C, corresponding o CO_2-densities $\approx$0.5 to 1.14 g/cm^3. Isochores for CO_2 densities of 1.05 to 1.10 g/cm^3 yield P of 6.5 to 8 kbars for peak metamorphic Ts (650-800°C; Bohlen et al., 1985). These P are consistent with peak Ps determined from mineralogic geobarometers. Many high density CO_2-rich inclusions occur in samples that were metamorphosed under conditions of low fCO_2, as inferred from either (1) the presence of wollastonite, or (2) values of fO_2 that were relatively reducing. Thus, two different methods of determining the composition of the peak metamorphic fluid phase (i.e, fluid inclusions and phase equilibria) yield very different results (i.e., CO_2-rich vs. CO_2-poor), and shows that the CO_2-rich fluid inclusions do not contain samples of the peak metamorphic fluid.

The P and T information derived from the investigation of fluid inclusions trapped after the peak of metamorphism may be used to constrain the retrograde P-T path. The presence of CO_2-rich inclusions with densities >1.1 g/cm^3 indicates that this P-T path was concave toward the T axis (on a P-T diagram) assuming entrapment at T >100 to 200°C. The mixed H_2O-CO_2 inclusions also constrain T and P during post-metamorphic cooling and uplift. Many of these mixed inclusions contain small amount of CO_2 (1-5 vol. %), with Th(L-V)CO_2 $\approx$16 to 24°C. Final melting of H_2O-CO_2 clathrates range from $\approx$6 to 10°C, corresponding to salinities up to 7.5 eq. wt. % NaCl. Attempts to homogenize the H_2O-CO_2 in these inclusions resulted in decrepitation and demonstrate that entrapment occurred at T >200 to 225°C. Isochores for these inclusions pass from $\approx$225°C at 3 to 4 kbar to $\approx$500°C at 7 to 9 kbar, indicating that during the first 300°C of cooling the decrease in P was <2 to 3 kbars. Thus, the retrograde P-T path was concave toward the T axis as inferred from the highest density CO_2-rich inclusions, and in agreement with studies of zoned Adirondack garnets (Bohlen, 1987). (Author's abstract)

LAMB, W.M., 1988b CO_2-rich fluid inclusions in granulites: Evidence for entrapment after the peak of metamorphism: Geol. Soc. India Memoir 11, p. 101-115. Author at Dept. Geol., Texas A&M Univ., College Station, TX 77843, USA.

CO_2-rich fluid inclusions have been found in samples from granulite-facies terranes around the world. These inclusions, if they were formed during the peak of metamorphism, may provide an important source of information concerning the nature of granulite-facies fluids. In at least some cases, however, CO_2-rich fluid inclusions in granulites clearly formed after the peak of metamorphism. Furthermore, investigation of fluid inclusions from the Adirondacks shows that high CO_2-densities, a property typically used to infer peak metamorphic formation of these inclusions, may occur in inclusions that were trapped after the peak event. Thus, inferences of peak-metamorphic fluid compositions based on fluid inclusions must be viewed with caution. (Author's abstract)

LAMB, W.M. and HOOVER, S.A., 1988, Fluid inclusion investigation of granulite retrogression associated with pegmatite intrusion: Parry Sound, Ontario (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A100. Authors at Dept. Geol., Texas A&M Univ., College Station, TX 77843.

Rocks from the Parry Sound region of Ontario experienced granulite facies metamorphism during the Grenville orogeny (approximately 1.1. Ga). After the peak of metamorphism the intrusion of pegmatite dikes often resulted in the formation of amphibolite facies assemblages in spatially associated rocks. This retrogression was presumably due to H_2O-rich fluids emanating from the pegmatite, and can be recognized in outcrop by a change from olive-colored granulites to gray amphibolite facies rocks (Schau et al. (1986) GAC-MAC). A sampling traverse was conducted within a single outcrop, from a pegmatite dike (≈ 0.5 m thick) through the amphibolite facies, and into granulites (traverse length ≈ 8 m). In the amphibolite facies samples hornblende grew at the expense of pyroxene. In the granulites, rims of amphibole and biotite on pyroxene and magnetite respectively indicate that some pegmatite fluids penetrated these rocks.

Microthermometric investigation of the FI in these samples has revealed the presence of both CO_2-rich (no visible H_2O) and H_2O-rich (with variable salinity) varieties (inclusions occur in quartz and are 5 to 40 µm in diameter). The CO_2-rich inclusions may be subdivided texturally into P and S inclusions. Most "primary" inclusions homogenize to a liquid at a T of -17.1 ± 0.5°C, corresponding to a CO_2 density of approximately 1.02 g/cm^3. P CO_2-rich inclusions occur in the granulite sample farthest from the pegmatite, and might be interpreted to contain peak granulite facies fluids. However, P CO_2-rich inclusions also occur in the pegmatite, which demonstrates that these inclusions formed after the peak of granulite facies metamorphism, and suggests they are related to pegmatite intrusion. Isochores for the P CO_2-rich inclusions, in conjunction with the granite solidus, indicate pegmatite intrusion occurred at a P ≈ 5 to 6 kbars.

Th for the H_2O-rich inclusions range from 93 to >400°C, and textural evidence indicates post entrapment changes (e.g., "necking") have affected some inclusions. However, inclusions with salinities up to 20 eq. wt. % NaCl have densities consistent with entrapment near the P's and T's inferred for pegmatite intrusion. Other lower salinity H_2O-rich inclusions must have formed later at lower T's. (Authors' abstract)

LAMB, W.M. and VALLEY, J.W., 1988, Granulite facies amphibole and biotite equilibria and calculated peak-metamorphic water activities: Contrib. Mineral. Petrol., v. 100, p. 349-360.

LAMBERT, D.D., MALEK, D.J. and DAHL, D.A., 1988, Rb-Sr and oxygen isotopic study of alkalic rocks from the Trans-Pecos magmatic province, Texas: Implications for the petrogenesis and hydrothermal alteration of continental alkalic rocks: Geochimica Cosmo. Acta, v. 52, p. 2357-2367. First author at Dept. Terrestrial Magnetism, Carnegie Inst. Washington, 5241 Broad Branch Rd., NW, Washington, DC 20015, USA.

Rb-Sr and O isotopic data for mid-Tertiary alkalic rocks for the Trans-Pecos magmatic province of west Texas demonstate that hydrothermal alteration and fluid/rock (cation exchange) interactions have affected the isotope geochemistry of these rocks. Leaching experiments demonstrate that the

Rb-Sr isotopic systematics of hydrothermally-altered continental alkalic rocks may be significantly improved, providing more reliable geochronologic and isotopic tracer information necessary in constructing precise models of mantle sources. (From the authors' abstract)

LANDAIS, P., BROSSE, E., CARISEY, J.C., MEYER, A.J. and PAGEL, M., 1988, Combined use of fluid inclusions, fission tracks, organic matter analyses and computer modelling for assessing the thermal history of Permian formations (Grand Canyon region, Arizona, U.S.A.) (abst.): Chem. Geol., v. 70, p. 185. Authors at CREGU, BP 23, 54501 Vandoeuvre-lès-Nancy Cedex, France.

An important part of the research in the field of basin analysis is devoted to the reconstruction of the thermal history of geological formations. Because of the complexity and the superimposition of geological events, the T pattern must be assessed by the combined use of different geothermometers and geochronometers. In this study, apatite fission tracks, fluid inclusions and organic matter analyses have been applied in order to determine the thermal history of Permian formations in the northern part of the Grand Canyon region (Arizona).

Burial reconstructions derived from geological studies indicate that maximum T ranging between 100 and 140°C have been reached during Cretaceous times. A maximum T of 137°C integrated over 50 M.a. has been derived from the fission track analysis. These ranges of T are consistent with minimum Tt obtained by fluid inclusions studies (75-140°C).

Fission tracks and burial hypotheses have been introduced in a kinetic model for organic matter maturation. The programs deliver the corresponding maturation state of the organic matter expressed in terms of Tmax Rock-Eval. The computed Tmax respectively average 445°C (fission track hypothesis) and 421°C (burial hypothesis). A comparison with organic geochemistry data from the Permian formation demonstrates that the two above hypotheses constitute a thermal framework for the organic matter evolution(Tmax ≈ 428°C). No evidence for any thermal event (T >150°C) have been found.

Additional results enable to date the beginning of the oil-window (120 ± 10 M.a.) and the regional uplift and erosion related to the Laramide orogeny (64 ± 5 m.a.). (Authors' abstract)

LANDIS, G.P. and BERNER, R.A., 1988a The composition of ancient air: Analysis of gas bubble inclusions in fossil amber (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 55. First author at U.S.G.S., Denver, CO 80225.

Amber of Late Cretaceous to Miocene age, collected from four well-documented sites, has been analyzed for the chemical composition of contained gases using time-resolved quadrupole mass spectrometry. Gas is present in amber as 1) primary bubbles entrapped between successive flows of tree resin, 2) irregular cavities in desiccation cracks and secondary planes, 3) matrix gas dissolved in the amber, and 4) matrix gas exsolved from the amber inorganically or by the tree, leaving dense clusters of small bubbles in 'milky' amber. We conclude that only gases released from primary bubbles represent original ancient air, modified after entrapment by aeroic respiration of micro-organisms. The O_2/CO_2 ratios for each primary bubble gas analysis from a locality vary, presumably the result of differing degrees of organic respiration. However, for all analyses, the value of $N_2/(O_2 + CO_2)$ is constant, and total oxygen content in ancient atmospheres can be calculated from $(O_2 + CO_2)$. Atmospheric oxygen appears to have varied from about 32% in one part of the Late Cretaceous (75-95 Ma), to about 22% in Late Eocene (40 Ma), to 15% in Oligocene-Early Miocene time

(25 Ma), and to 21% today. As a check on our methods, modern atmospheric gas composition is obtained for all major gases (N_2, O_2, Ar, CO_2) from primary gas bubbles in modern New Zealand resin. Variable O_2 concentrations in the geologic record confirm theoretical isotope mass balance calculations. These variations suggest that the atmosphere has evolved, along with plant and animal life, through Phanerozoic time. (Authors' abstract)

LANDIS, G.P. and BERNER, R.A., 1988b, "Is the air in amber ancient?" (Technical comments): Science, v. 241, p. 717-724.

Extended discussions, by H.B. Hopfenberg et al., C.W. Beck, K.E. Chave and S.V. Smith, and Y. Horibe and H. Craig, of Berner & Landis, 1987b,c, in Fluid Inclusion Research, v. 20, p. 34, plus authors' response. (E.R.)

LANE, Tom, 1988, Deformation history of the Paleozoic Humber Platform recorded in dolostone-sulphide complexes, Lower Ordovician St. George Group, Daniel's Harbor, western Newfoundland: GAC, MAC, CSPG, AGC, AMC and SCGP Joint Annual Mtg., Program with Abst., v. 13, p. A71. Author at Dept. Earth Sci., Memorial Univ. Newfoundland, St. John's, NF, A1B 3X5.

Complex relationships between dolostones, breccias and sulphide deposits at Newfoundland zinc mines record a long history of faulting and fracturing of the Humber Platform. Six discrete phases of faulting or fracturing and dolomitization are recognized on the basis of stratigraphic, structural and petrographic relationships. (1) Early Ordovician fracturing along NE-SW lineaments influenced carbonate sedimentation. (2) Faulting along the same lineaments during Middle Ordovician time exposed the platform, locally leading to subsurface karst brecciation. Near-surface dolomitization converted muds to microcrystalline dolostone. (3) After collapse and subsequent burial of the platform by the Taconic Allocthon during later Middle Ordovician time, karst breccias and their deformed margins were pervasively altered to discordant bodies of medium crystalline dolostone. P solution-related dolomitization replaced lime muds with ubiquitous mottles of fine to medium crystalline dolomite. (4) Post-burial fracturing allowed formational fluids to move through the carbonates and precipitate zoned dolomite cements. (5) During initial Acadian deformation and continued burial to a maximum of 1000 to 3000 m earlier dolostones were overprinted by the coarse dolostone/sphalerite complexes. Several phases of fracturing and dissolution punctuated 8 stages of sulphide and dolomite deposition. Hypersaline, hydrothermal source fluids (fluid inclusion Th's of 100° to 185°C and salinities of 20 to 30 wt.% NaCl) migrated from basement depths through deep fracture systems. (6) During the Devonian(?) uplift of the Long Range Inlier regional faulting displaced the coarse dolostone/sphalerite complexes. Late stage dolomitization and hematite precipitation occurred along these faults. (Author's abstract)

LANG, J.R. and EASTOE, C.J., 1988, Relationships between a porphyry Cu-Mo deposit, base and precious metal veins, and Laramide intrusions, Mineral Park, Arizona: Econ. Geol., v. 83, p. 551-567. Authors at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

Full paper for abstract by Lang et. al., 1987, in Fluid Inclusion Research, v. 20, p. 224. (E.R.)

LANZIROTTI, Antonio and CONDIE, K.C., 1988, Origin and tectonic significance of early Proterozoic leucogranites and high-pressure granulites in the Wet Mountains, Colorado (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 121-122. Authors at Dept. Geosci., New Mexico Tech., Socorro, NM 87801.

Syntectonic leucogranites (LG) intrude an early Proterozoic, largely metasedimentary supracrustal succession in the West Mountains of central

Colorado. Supracrustal rocks are chiefly plg-qtz-biot paragneisses and associated granulites containing opx, garnet and in some cases, scapolite. Most of the terrane is comprised of retrograde amphibolite-facies mineral assemblages with only minor remnants of granulites preserved. Metasediment protoliths appear to have been chiefly arc-related quartz-wackes. Granulites are depleted in K, Rb, Cs, U and Th much like high-P granulites from India and Scotland. Fluid inclusions in granulites are CO_2-rich with estimated entrapment P of 6-7 kb and scapolite-bearing assemblages suggest minimum metamorphic T of 700-800°C. LG are largely concordant, deformed tabular bodies comprised of subequal amounts of plg, KF and qtz with minor biotite. They are strongly peraluminous, have high K_2O/Na_2O ratios and contain abundant metasediment and granulite xenoliths. LG plot close to the 1 kb cotectic in the system Ab-Or-Q-An suggesting low water contents. They are also strongly enriched in LILE, have steep REE patterns (La/Yb > 15) with negative Eu anomalies and have within-plate or syncollisional characteristics in terms of Rb-Y-Nb-Ta-Hf contents. Geochemical modeling indicates that LG can be produced by batch melting of surrounding paragneisses.

Wet Mountains supracrustal rocks were probably deposited in a continental-margin back-arc basin prior to 1720 Ma. Collision of the Pecos arc from the south at about 1710 Ma resulted in deep burial of the succession and high-P CO_2 metamorphism (7-8 kb). Water purged from the rocks during metamorphism promoted partial melting of metasediments giving rise to LG. Uplift was accompanied by widespread retrograde metamorphism to amphibolite-facies grade. (Authors' abstract)

LAPTEV, Yu.V., 1988, Bismuth: Possibility of hydrothermal transport, conditions of mineral precipitation (abst.): Terra cognita, v. 8, p. 185. Author at Siberian Br. USSR Acad. Sci., Inst. Geol. & Geophys., Novosibirsk, USSR.

The formation of the hydrolysis products $Bi(OH)_2^+$, $Bi(OH)^0{}_3$ and $Bi(OH)_4^-$ has been studied when dissolving α-Bi_2O_3 in water solutions at T = 348, 473 and 573 K and using high T spectrophotometry parallely[sic]. The form $Bi(OH)^0{}_3(aq)$ has been found to be [present?] in a wide pH range (2.5-12) at 573 K. The values of $\Delta G°_{f,T}$ (kJ/mol.) -568.19 (298 K); -506.26 (473 K) and -472.29 (573 K) have been obtained for this form. Thermodynamic calculations of bismuthine dissolution in chloride solution have shown the predominance of $BiCl_3^{3-n}$ complexes in acid and alkaline solutions, respectively. The tendency of formation of metallic bismuth has been found in alkaline solutions. Bismuth precipitation at concentrations lower than [a] geochemically significant one (10^{-6} m) at T = 573 K and C_{NaCl} = 1 m occurs at pH >4 and $C(H_2S) > 10^{-4}$ m. The calculations confirm high-T conditions of bismuthine genesis in rare-metal quartz veins at greisenization of host rocks. (Author's abstract)

LARGE, Ross, HUSTON, David, McGOLDRICK, Peter, McARTHUR, Garry and RUXTON, Peter, 1988, Gold distribution and genesis in Paleozoic volcanogenic massive sulphide systems, eastern Australia (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 121-126. First author at Univ. Tasmania, Hobart.

Presents a diagram (Fig. 5) of T (presumably Th) vs wt% NaCl, with areas delineated for various types of Au ores and for Au transport by $AuCl_2^-$ or $Au(HS)_2^-$. (E.R.)

LARGE, Ross and WEDEKIND, Richard, 1988, Geological controls on high grade gold mineralization at Tennant Creek, N.T. (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 73-78. Authors at Dept. Geol., Univ. Tasmania, G.P.O. Box 252C, Hobart, Tas. 7001.

Quotes isotope and inclusion data from the literature. (E.R.)

LASSEY, K.P. and BLATTNER, Peter, 1988, Kinetically controlled oxygen isotope exchange between fluid and rock in one-dimensional advective flow: Geochimica Cosmo. Acta, v. 52, p. 2169-2175.

LAWRENCE, J.R. and TAVIANI, M., 1988, Extreme hydrogen, oxygen and carbon isotope anomalies in the pore waters and carbonates of the sediments and basalts from the Norwegian Sea: Methane and hydrogen from the mantle?: Geochimica Cosmo. Acta, v. 52, p. 2077-2083. First author at Dept. Geosci., Univ. Houston, University Park, Houston, TX 77004, USA.

D/H ratios in the pore waters of the sediments from the Norwegian Sea decrease as a function of depth to values as low as -14‰. Oxygen isotope ratios in the pore waters and carbon and oxygen isotope ratios in carbonates both in the sediments and basalts are low. Extensive alteration of basalt has been given as the explanation for the low oxygen isotope ratios.

Material balance calculations suggest that alteration of volcanic material and oxidation of organic matter cannot explain the hydrogen and carbon isotope anomalies. Arguments are presented suggesting that methane and hydrogen from the mantle are oxidized to carbon dioxide and water by sulfate and ferric iron in the basaltic crust to yield the low hydrogen and carbon isotope ratios. (Authors' abstract)

LAYNE, G.D. and SPOONER, E.T.C., 1988, Cassiterite precipitation as a result of wall rock reduction alteration during late stage skarn formation in the JC tin skarn, Yukon Territory, Canada (abst.): Geol. Soc. Am. Abstract Programs, v. 20, p. A93. Authors at Dept. Geol, Univ. Toronto, Toronto, Ont., Canada, M5S 1A1.

In the JC skarn, late stage (Stage IV) biotite-quartz-fluorite skarn is the only stable assemblage in which Sn occurs as cassiterite rather than as silicate-bound tin in garnet, amphibole, epidote and other minerals. Fluid inclusion microthermometry implies that cassiterite formed over a T range of 430 to 560°C, at an estimated P of ~750 bars. Stage IV fluids ranged in salinity from 6 to 12 m ΣCl and have a wt. % ratio of NaCl to KCl of ~3.5:1. Mineral stability calculations imply that the oxygen fugacity within the skarn at this stage was within +1 log unit of the quartz-magnetite-fayalite (QMF) buffer. Calculations based on the experimental solubility data of Wilson (Ph.D. Thesis, The Johns Hopkins Univ., 1986), indicate that stage IV fluids may have carried more than 1 ppm Sn in solution as chloride complexes of bivalent Sn (predominantly $SnCl^+$ and $SnCl^\circ_2$) over the entire T range deduced from fluid inclusion microthermometry. At T >550°C stage IV fluids may have carried more than 700 ppm Sn in solution.

The highest Sn grades encountered in the deposit (>0.35 wt.% Sn) are found within a restricted zone immediately overlying the skarn-granite contact. This zone corresponds to a localized concentration of stage IV biotite-quartz-fluorite-cassiterite which has replaced earlier stage II amphibole-magnetite skarn. There is strong textural evidence that cassiterite was precipitated at stage IV by a process involving the alteration of magnetite and amphibole to produce biotite and quartz, (...) or by a similar reaction which does not involve magnetite. The absence of similar wall rock-reduction/proton-consumption alteration reactions in pyrrhotite-rich stage II skarn and pyroxene-rich stage I skarn, even where the original interstitial calcite in these rocks has been extensively replaced by stage IV fluorite, may explain the paucity of cassiterite mineralization hosted by these particular assemblages. (From the authors' abstract by E.R.)

LAYNE, G.D., SPOONER, E.T.C. and LONGSTAFFE, F.J., 1988, Stable isotopic and fluid inclusion evidence for variable mixing of magmatic and meteoric water during the formation of the multi-stage JC tin skarn, Yukon Territory, Canada (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A334. First author at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

The measured $\delta^{13}C$ and $\delta^{18}O$ compositions of calcite from premetasomatic skarnoid (stage 0-grossularite + diopside ± calcite) rocks are modelled as the result of decarbonation of the original protolith marble, coupled with the infiltration of variable amounts of meteoric water, during the isochemical contact metamorphism which preceded skarn formation. The δD and $\delta^{18}O$ analyses of the earliest metasomatic skarn silicates imply that initial metasomatism (stage I - andradite + hedenbergite) was produced by predominantly magmatic fluids and that stage II (Fe-amphibole + magnetite) skarn was subsequently formed by magmatic water mixed with as much as 50% meteoric water.

The δD and $\delta^{18}O$ analyses of silicates from stage III (epidote + quartz + calcite ± axinite) skarn, coupled with the data from primary fluid inclusions in epidote and axinite, are consistent with this stage having been formed by fluids which contained a major component of highly saline magmatic water, diluted by very low salinity water which was probably meteoric in origin. Pseudosecondary inclusions of very low salinity water in stage III epidote may be remnants of this meteoric water, which comprised up to 40% of the skarn-forming fluid at stage III. The $\delta^{13}C$ and $\delta^{18}O$ compositions of stage III calcite imply the participation of an additional fluid component which had equilibrated with the protolith marble at high T. Stable isotope analyses of coexisting quartz and biotite from stage IV (biotite + quartz + fluorite ± cassiterite) skarn imply that skarn-forming fluids at stage IV had reverted to being predominantly magmatic. This interpretation is consistent with the high salinities (6 to 12 m ΣCl) and high trapping T (430 to 560°C) calculated for primary fluid inclusions in stage IV cassiterite.

The $\delta^{13}C$ and $\delta^{18}O$ values determined for carbonates from stage V (calcite + pyrite ± marcasite) mineralization imply that, at this stage, meteoric water which had initially equilibrated at low T (<100°C) with the protolith marble mixed in variable proportions with a second fluid which was in equilibrium with the cap of the underlying granite. The narrow range of $\delta^{34}S$ values for all skarn sulphide minerals (-1.0 to +2.5 per mil) is consistent with a magmatic source for sulphur throughout skarn formation. (Authors' abstract)

LAZAR, Boaz and HOLLAND, H.D., 1988, The analysis of fluid inclusions in halite: Geochem. Cosmo. Acta, v.52, p.485-490. First author at Marine Bio. Lab., The Hebrew University, Eilat, 88103, Israel.

A technique has been developed to drill into fluid inclusions in halite, to extract the inclusion fluids, and to determine the concentration of all of the major and some of the minor constituents in these fluids. The minimum diameter of usable fluid inclusions is ca. 250 μm. After dilution, the fluids are analyzed by ion chromatography and coulometry. Uncertainties in the concentration of the major cations and anions is on the order of 4%. The analytical scheme provides much more precise analyses of inclusion fluids than have been available to date. The analyses are a useful starting point for reconstructing the composition of the seawater from which the evaporite brines evolved. (Authors' abstract)

LEACH, D.L., HOFSTRA, A.H. and LANDIS, G.P., 1988, Analyses of volatiles in fluid inclusions and the application of these data to the study of precious metal veins in the Coeur d'Alene district Idaho, U.S.A. (abst.):

Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 205-210. Authors at U.S. Geol. Survey, Box 25046, Federal Center, Denver, CO 80225-0046.

Laser Raman spectroscopy and mass spectrometry (detailed procedures described) were used to study the gases in inclusions. The three types of veins differ in N_2:CO_2:HC:Ag-rich are N_2-CO_2 with no HC; Au-rich are CO_2; Zn-rich have much HC + CO_2 ± N_2. Ore deposition occurred at ~250 to 350°C and 1-3 kbar, with changing fO_2 conditions during metamorphism causing the change in gas composition. (E.R.)

LEACH, D.L., LANDIS, G.P. and HOFSTRA, A.H., 1988, Metamorphic origin of the Coeur d'Alene base- and precious-metal veins in the Belt basin, Idaho and Montana: Geology, v. 16, p. 122-125. Authors at U.S. Geol. Survey, MS 973, Box 25046, Federal Center, Denver, CO 80225.

Fluid inclusions, geochronology, and field studies show that the world-class base- and precious-metal veins of the Coeur d'Alene district, Idaho and Montana, are the product of deformation coupled with regional metamorphism of the Belt basin around 850 Ma. Fluid inclusion data show that the mineralizing solutions were complex CO_2-CH_4-C_nH_m-N_2-H_2O-NaCl fluids that changed in composition from CH_4-C_nH_m-rich fluids in the older Zn-rich veins to CO_2-rich fluids in the younger Ag-rich veins. Ore deposition occurred at about 250 to 350°C and at P in excess of 1 kbar. (Authors' abstract)

LE BRETON, N., 1988, Co_2-content of granulitic cordierites: A new infrared analytical method (abst.): Terra cognita, v. 8, no. 3, p. 255.

LECHLER, P.J. and HSU, L.C., 1988, Interpretation of soil nitrite-ammonium ratios: A new PGE prospecting technique (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 56. Authors at Nevada Bureau of Mines & Geol., Univ. Nevada, Reno, NV 89557, USA.

Ammonia is a common constituent of both igneous and hydrothermal systems. Upon weathering ammine-bearing minerals and fluid inclusions are destroyed and ammonium is dispersed to the soil profile. Ammonium is thermodynamically unstable in this environment and will oxidize to nitrogen, nitrite, and nitrate. Laboratory studies have shown that platinum catalyzes the ammonium-nitrite oxidation step. This suggests that pedogeochemical nitrite/ammonium variations might provide a valuable, indirect PGE prospecting tool for buried hydrothermal- or magmatic-mineralization. While PGE's are relatively immobile in the weathering environment, ammonium and nitrite are quite mobile even in arid, alkaline environments.

A case-study example at a newly-discovered PGE deposit in Clark Co., Nevada, is used to demonstrate the usefulness of ammonium- and anion-geochemistry in prospecting for PGE mineralization. The Gingerload Prospect is a stockwork vein-type hydrothermal deposit hosted by a Mesozoic granitic stock which intrudes Proterozoic metamorphic rocks. PGE concentrations as high as 1840 ppm Pt, 3940 ppm Os + Ir, 120 ppm Rh, 17 ppm Pd, and 10 ppm Ru have been recorded in a base- and precious-metal quartz vein 40 feet underground.

Soil PGE abundances do not indicate the presence of underlying PGE mineralization; soil Au, Ag, and base metals indicate mineralization and nitrite/ammonium implies PGE content. (Authors' abstract)

LEET, R.C., 1988, Saturated and subcooled hydrothermal boiling in groundwater flow channels as a source of harmonic tremor: J. of Geoph. Res., v.93, n.B5, p.4835-4849.

LEHRBERGER, Gerhard, 1988, Gold-antimonite deposits in marine sediments of the eastern Cordillera of the Bolivian Andes (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 319-321. Author at Lehrstuhl für Angewandte Min. und Geochemie, Tech. Univ. München, Lichtenbergstr. 4, D-8046 Garching, West Germany.

Preliminary data show two types of inclusions. The most common are water-rich, and have a range of Th of 130 to 200°C. Mixed CO_2-H_2O inclusions occur in some samples, with a Th of about 275°C. (From the author's abstract)

LEUBE, A. and HIRDES, W., 1988, New aspects on disseminated and vein type gold mineralization in Ghana/West Africa (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abstract Series, no. 23, p. 149-152. Authors at BGR, Stilleweg 2, D-3000 Hannover, FRG.

Mentions 390°C as the "highest recorded" Th. (E.R.)

LHÉGU, J., JÉBRAK, M. and TOURAY, J.C., 1988, Fluorite and barite deposits in France: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 297-307. First author at Bureau de Recherches Géol. & Min., B.P. 6009, F-45060 Orléans Cedex 02, France.

France is one of the leading producers of fluorite and barite. Four main types of deposits are distinguished: (1) stratiform deposits in Paleozoic rocks with major deposits at Arrens (barite) and Escaro (fluorite); (2) karst and vein deposits in Paleozoic carbonate rocks under the Triassic unconformity with only small occurrences, mainly of barite; (3) vein deposits in the Hercynian basement and Mesozoic cover with two subtypes of fluorite and barite deposits: S-veins related to extensional zones during compressive tectonic activity, and E-veins associated with normal faults; and (4) stratiform deposits in the Mesozoic cover including large deposits.

Geochemical investigations (Pb isotopes, fluid inclusions and REE) are discussed and two genetic models (mixing and cooling processes) are proposed to explain the characteristics of these deposits. (Authors' abstract)

LI, Benchao, 1988, Geochemical studies of fluid inclusions from Chishui gas field in Guizhou Province: Geochimica, no. 3, p. 248-256 (in Chinese; English abstract). Author at Inst. Geochem., Acad. Sinica.

Fluid inclusions both in calcite crack fillings and in late-stage gypsum from the carbonate reservoir in the Chishui gas field, Guizhou Province have been studied. Gas composition and gaseous hydrocarbon composition of the inclusions have been determined by separate heating decrepitation-gas chromatography and vacuum ball milling-gas chromatography. It is concluded that the major prospecting strata are the Permian Maokou Formation in this area. (Author's abstract)

LI, Tongjin, 1988, Experimental studies of the solubility of cassiterite and the extraction of tin from granitic melt: Geochimica, no. 2, p. 150-160 (in Chinese; English abstract). Author at Inst. Geochem., Acad. Sinica.

Experiments on cassiterite solubility indicate that the solubility of cassiterite can be enhanced by increasing either acidity or alkalinity in hydrothermal solutions. This fully reflects the duality of Sn. The minimum solubility of cassiterite is found in neutral solutions. F and Cl coordination compounds of Sn can alternate with the hydroxy coordination compounds with pH changes in the solutions. In this case, F^- and Cl^- and OH^- can be substituted with each other. Dissolution reaction of cassiterite is a reducing reaction. High T and acidic reducing environment are favorable for the dissolution of cassiterite and the transport of Sn^{+2} coordination compounds in fluid phases or solution phases.

High-T fluids of fluorides and chlorides can all dissolve, extract and enrich Sn to form coordination compounds of F and Cl. However, F may play a more important role than Cl. The coordination compounds of F are more stable and efficient than those of Cl in the transport and enrichment of Sn in the melts and solutions.

The solubility of cassiterite and the amount of Sn extracted from granitic melt depend on not only T, P, pH and Eh in the fluids (or solutions), but also the amounts of dissociated F^- and Cl^- in the fluids. (Author's abstract)

LIANG, Feng and CHAO, Yuan, 1988, Geological features of fluid inclusions in quartz in the Xiaoqinling gold deposit in Shaanxi: Geol. of Shaanxi, v. 6, no. 1, p. 8-21 (in Chinese; English summary).

Indexed under "Fluid Inclusions." (E.R.)

LIEBLER, G.S., 1988, Geology and gold mineralization at the Picacho mine, Imperial County, California, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 453-472. Author at 390 Freeport Blvd., #12, Sparks, NV 89431.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 233-234, 1987. (E.R.)

LIGANG, Zhang, 1988, A study on the stable isotopes of some W-Sn deposits in southern China (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 85.

Same abstract as Zhang, Ligang, 1988 (this volume). Presumably entered in abstract volume under both family name (Zhang) and given name (Ligang). (E.R.)

LINNEN, R.L. and WILLIAMS-JONES, A.E., 1988, An example of boron-rich tin-tungsten mineralization: The Pilok district, western Thailand (abst.): GAC/MAC Program with Abstracts, v.13, p.A74. Authors at Dept. of Geol. Sci., McGill Univ., 3450 University St., Montreal, H3A 2A7.

Seven deposits are currently being mined for cassiterite and wolframite in the Pilok district, western Thailand, close to the contacts between leucogranite and pelitic to psammitic metasediments. The leucogranite is composed of quartz, two feldspars, ± tourmaline, ±muscovite, ±garnet, and occurs at the margin of a garnet-bearing biotite granite. Pegmatite pods in the leucogranite are less than one meter across, and contain quartz, feldspars, and minor muscovite, tourmaline, and/or beryl. Pegmatite pods are generally barren, but rarely host wolframite or molybedenite mineralization. Tourmaline is the earliest and most widespread alteration mineral. Most, if not all, of the tourmaline in the leucogranite is hydrothermal in origin. The metasediments are also intensely tourmalinized at the contacts with leucogranite. Minor fluorite replacement of plagioclase in the leucogranite occurred at this stage. Quartz-K-feldspar veins cut tourmaline alteration, and host the bulk of the wolframite. Quartz veins with greisen-cassiterite-sulphide mineralization overprint earlier alteration/veining. In the greisen, feldspars and tourmaline are replaced by quartz, muscovite, and minor fluorite and beryl. Cassiterite occurs alone or with combinations of pyrite, chalcopyrite, sphalerite, and arsenopyrite. Four types of fluid inclusions have been identified in quartz, cassiterite, tourmaline, and beryl: 1) vapor-rich, including carbonic; 2) three-phase H_2O-CO_2, H_2O-rich; 3) liquid-rich, two-phase aqueous; 4) solid-bearing liquid-rich aqueous. Textures and preliminary microthermometric data suggest that inclusion types 1 and 2 reflect fluid immiscibility over part of the mineralization sequence between 250° and 350°C. (Authors' abstract)

LIPPOLT, H.J. and WEIGEL, Erich, 1988, ^{4}He diffusion in ^{40}Ar-retentive minerals: Geochimica Cosmo. Acta, v. 52, p. 1449-1458. Authors at Lab. Geochron., Ruprecht-Karls-Univ. Heidelberg, Im Neuenheimer Feld 234, D 69 Heidelberg, FRG.

^{4}He vacuum diffusion experiments were carried out by stepwise degassing minerals normally used in K-Ar chronometry such as hornblende, nepheline and others. The study aims at ^{4}He diffusion parameters for uppermost crustal T and thus at He retentivities of the minerals. The results indicate long-time near-quantitative ^{4}He retention in hornblende, pyroxene, langbeinite and perhaps nepheline, for 0.5 mm grains at least at T below about 70°C. Sanidine and muscovite lose ^{4}He over geologic periods at lower T. Only the minerals of the first group are possible (U + Th)/He chronometers or geothermometers provided that other dating problems, such as alpha loss and U migration, can be settled. Closure T for rapidly cooling 2 mm hornblende crystals are found to be in the range of 190 to 170°C. Tentative U-He indices indicate that diffusion parameters of the same order of magnitude as determined for the He-retentive minerals may be used to select minerals to be further examined for their (U + Th)/He datability, e.g., ore minerals. (Authors' abstract)

LISLE, R.E. and DESROCHERS, G.J., 1988, Geology of the Hilltop gold deposit, Lander County, Nevada, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 101-117. First author at Callahan Mining Corp., P.O. Box 12247, Reno, NV 89510.

The Hilltop Au deposit is within the Battle Mountain-Eureka mineral belt in the northern Shoshone Range, Lander County, Nevada. Historic Au production from the Hilltop Mine came from a steep, narrow, discordant breccia and from thin quartz veins. Discovery of bulk-mineable, concordant breccia-hosted Au mineralization resulted from evaluation of existing drill data, underground geologic mapping, and recognition of coincident Au, Ag, As and Sb geochemical anomalies. Moderate, pervasive quartz-sericite-pyrite alteration associated with low-grade, disseminated, Au-Mo mineralization occurs in sedimentary rocks and dacite porphyry. Discordant and concordant breccias are developed in altered chert in the hanging wall of the Hilltop Mine fault.

Early chalcedonic quartz was followed by euhedral quartz, pyrite, (partly pseudomorphous afer marcasite), chalcopyrite, sphalerite, galena, tetrahedrite, and Au which were deposited as open-space fillings in discordant breccias and veins. Concordant breccia mineralization formed by at least three mineralogically and temporally distinct, but spatially overlapping, events represented by the following assemblages: 1) quartz-carbonaceous matter-pyrite-arsenopyrite-tennantite/tetrahedrite-Au (As-rich event); 2) quartz-barite-stibnite-Au-Ag (Sb-rich event); and 3) marcasite-pyrite-barite (late barren event).

Cu-Mo mineralization preceded brecciation and movement on the Hilltop Mine fault. Discordant breccia and veins were mineralized and then subsequently offset on the Independence fault prior to concordant mineralization. Recurrent tectonic and hydrothermal brecciation accompanied Au introductions. (From the authors' abstract by E.R.)

Inclusion studies (by T.J. Reynolds) show two types, I (Th in liquid) and II (Th, probably <200°C, in vapor). Early Cu-Mo mineralization T

>250°C, salinity <5%. Breccia mineralization shows Th ~200-230°C and salinity <1%; late stage Th 120-140°C and ~4%. (E.R.)

LITHERLAND, A.E., ALLEN, K.W. and HALL, E.T., eds., 1987, Ultra-high-sensitivity mass spectrometry with accelerators: The Royal Soc., 172 pp.
Of interest for the possible analysis of fluid inclusion samples, but somewhat out of date as of the date of publication. (E.R.)

LITTLE, S.A., STOLZENBACH, K.D. and GRASSLE, F.J., 1988, Tidal current effects on temperature in diffuse hydrothermal flow: Guaymas Basin: Geophys. Res. Lett., v. 15, no. 13, p. 1491-1494. First author at Centre for Water Res., Univ. Western Australia.
A twelve day record of T collected from the diffuse flow area of a Guaymas Basin hydrothermal site exhibits variations, from a minimum of 3.05°C to a maximum of 4.87°C, whose periodicity is correlated with tides measured at the nearby town of Guaymas. A simple model, based on the hypothesis that T variations result as changes in tidal bottom currents induce changes in the height of the thermal boundary layer, is in good quantitative agreement with observed T for most of the record. The success of this model illustrates that the effects of tidal currents can be strong enough to dominate the time variability of a T signal at a fixed point in hydrothermal fow. Therefore, tidal currents must be taken into account when using T measurements to estimate time varying heat fluxes from hydrothermal diffuse flow regions. (Authors' abstract)

LITVIN, A.L., VOZNYAK, D.R., MELNIKOV, V.S. and RAZDOROZHNY, V.F., 1988, Ongonites of the Ukraine and conditions of their crystallization: Geolog. Jour., v. 48, p. 112-118 (in Russian; English abstract).
Structural-textural peculiarities, chemical and mineral composition of the aphyric and porphyritic rocks dikes crosscutting the Precambrian amphibole-pyroxene shales and mylonitized gneisses are identical to those of ongonites. The basic minerals of phenocrysts are quartz, alkaline feldspars (albite, anorthoclase-microcline of the micro- and cryptoperthite structure), and mica (lepidolite and zinnwaldite). Quartz, mica, alkaline feldspars, topaz, crystallized glass form their bulk. Differences are observed in the chemical and mineral compositions of the axial and contact parts of dikes. Studies of the mineral-forming medium inclusions in quartz indicates the existence of fluoride melt at the final stage of crystallization of quartz phenocrysts at ~1140°C and under high P. (Authors' summary)

LIU, Bin, 1988, Calculation of formation temperatures and pressures by use of thermodynamic equations for equilibrium of fluid inclusions with paragenetic host minerals: Sci. Sin., Ser. B (Engl. Ed.), v. 31, no. 3, p. 344-353 (in English). Author at Dep. Geotech. Eng., Tongji Univ., Shanghai, PRC.
Fluid inclusion Th are not equal to the Tt in most cases. As long as P corrections are made, the Tt can be obtained but Pt are hard to obtain. Only if the geothermometer and geobarometer are based on paragenetic associations of minerals have >2 equations for a series of paragenetic minerals can their solution be obtained. In general, this requirement is difficult to satisfy; however, to establish an equilibrium equation is much easier. Thus, an equilibrium equation for paragenetic minerals and a thermodynamic equation of trapped fluid inclusion were used and simultaneously solved to determine the Tt and P for paragenetic minerals or fluid inclusions. (C.A. 109: 153324c)

LIU, Huifang and YUE, Shucang, 1988, A geochemical and thermodynamical study on the veinlike lead-zinc deposits in eastern Zhejiang: Min. Deposits, v. 7, no. 4, p. 52-64 (in Chinese; English abstract). Authors at Hefei Polytech.

Univ., Hefei, Anhui, China.

The calculated mineral-forming environments and the data on the solubilities of ore minerals enable the authors to analyze and calculate the transportation and precipitation mechanism of the main ore-forming elements. During stage two, Zn and Pb were mainly transported as chloride complexes and precipitated as a result of decrease in T and increase in pH of the fluids. Besides, mixing of the ore-forming fluids with a more dilute solution is possibly another reason for precipitation. In a few ore districts dominated by oxidized sulfur species, the decrease in oxygen fugacity might also have caused the precipitation of considerable amounts of ore materials. At stage three, Pb and Zn were mainly transported in the form of sulfur complexes and precipitated most possibly through the decrease in T and increase in oxygen fugacity. The ore-forming fluids at this stage had relatively low capacity of metal transportation, suggesting the probable existence of a large and prolonged hydrothermal circulating system.

The veinlike Pb-Zn deposits in eastern Zhejiang occur mainly within the Jurassic-Cretaceous acid pyroclastic rocks, having similar geological environments.

According to the Th and [Tm ice] of fluid inclusions, the T of the main mineralization period are ~270°C to 330°C for the second stage and 200°C or so for the third; the salinities of the ore-forming fluids are 7 to 11 wt% NaCl eq. for stage two and 3 to 4 wt% NaCl eq. for stage three. On the basis of the information about mineral assemblages, mineralization T and composition of ore-forming fluids, thermodynamic calculation and analysis have been made for other factors of physicochemical environment, such as pH, sulfur fugacity, and oxygen fugacity. For stage two, pH is 4.2 to 5.7, sulfur fugacity about $10^{-11.5}$ to 10^{-8} bar, and oxygen fugacity is about 10^{-35} to 10^{-29} bar; for stage three, pH is 5.6 to 7, sulfur fugacity is about 10^{-11} to $10^{-15.7}$ bar and oxygen fugacity is about $10^{-43.5}$ to 10^{-39} bar. Although different deposits are slightly different in sulfur fugacity and oxygen fugacity, they are mostly in an environment dominated by reduced sulfur species. (Authors' abstract)

LIU, Xiaoshan, WU, Chengyu and HUANG, Biao, 1988, Origin and evolution of the hydrothermal system in Nannihu-Sandaozhuang molybdenum (tungsten) ore deposit, Luanchuan County, Henan Province: Geochemistry (Chinese), v. 7, p. 97-108. Authors at Dept. Geol., Nanjing Univ., PRC.

In this paper genetic problems and evolution of the hydrothermal system in the Nannihu-Sandaozhuang molybdenum (tungsten) deposit are dealt with in the light of T, P, and salinity and composition data obtained from fluid inclusions and of the stable isotopic composition of hydrothermal minerals. (From the authors' text by H.E.B.)

LIU, Zhimin, 1988, The mechanism of the formation of decrepitation and stress crests on the temperature sounding curves by using quartz decrepitation method and its application to the gold ore studies: Geol. of Shaanxi, v. 6, no. 2, p. 66-77 (in Chinese; English abstract). Author at Bureau of Geol. & Min. Resources of Shaanxi Province.

Through the test and the statistics of 965 various quartz samples, quartz can be divided into four types; mountain crystal (including native and artificial crystals); quartz aggregates containing no or < 5 μm fluid inclusions; quartz aggregates containing > 5 μm fluid inclusions; quartz monocrystal containing some fluid inclusions. On the basis of the above and by using the basic theory and experiments of anomalous optic orientation features, thermophysical properties, thermal stress, mechanics of materials, stress mineralogy, mechanical properties of rock and energy conversion in quartz etc., the writer has calculated the thermal stress of quartz on the main axial direction between 100°C and 1000°C. The calculated result has been proved to correspond with the actual situation by observing micro-decrepitation and examining decrepitated sand thin sections. So, this has qualitatively and quantitatively explained the mechanics of decrepitation and also proved that the peak of quartz decrepitation at 573°C is formed by thermal stress aggregation, thus calling it the stress peak. Because decrepitation and stress peaks are all present in different stages of stress formation during the process of heating quartz samples, Td and the F/V values of stress peaks are obtained by using the methods of total analysis and handling in separated stages for decrepitation curves of quartz. In the subject of "Study of the evaluation marks of the Au vein bodies in the Xiaqinling area of Shaanxi and the exploration," through application of the results from about 200 samples, it has been proved that these values obtained by using the above methods can play a certain guide role in evaluation of ore potentiality, such as Td of quartz reflecting the variation regularities of regional thermal halo; the variation tendency of Td in vertical direction; a certain initial relation existing in Td and mineral associations and ore-bearing properties; a certain relation existing between the intervals of Td and the occurrence of ore bodies; the relational coefficient of about 60% in the F/V value of quartz stress peak and Au ore grade. In spite of the above there are still some problems to be solved in the future. (Author's abstract)

LIVESEY, C.L., BAKSI, A.K. and BYERLY, G.R., 1988, Detrital sanidines from the Cretaceous Woodbine formation: Source rock implications (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, p. 122. Authors at Dept. Geol. & Geophys., Louisiana State Univ., Baton Rouge, LA 70803.

Feldspathic lithic graywackes of the Upper Cretaceous Woodbine formation are rich in volcaniclastic material. This includes unaltered, colorless, transparent sanidine grains. Microprobe analyses of large (up to .01 mm), melt inclusions (now glassy) present in the sanidine grains will yield direct evidence concerning the liquid line of descent of the magma. $^{40}Ar/^{39}Ar$ data from these sanidines will reveal the timing of the volcanic activity that produced these volcaniclastic deposits. The source of the volcaniclastic grains, although long speculated on, remains ambiguious. Four major, Late Cretaceous alkaline igneous fields occur along the northern rim of the Gulf of Mexico Basin. (From the authors' abstract)

LOMBAARD, A.F., GÜNZEL, A., INNES, J. and KRÜGER, T.L., 1986, The Tsumeb lead-copper-zinc-silver deposit, South West Africa/Namibia: Min. Deposits of S. Africa, v. 2, p. 1761-1787.

An extensive study of the deposit, that includes a brief section (p. 1781-1782) giving unpublished 1973 inclusion Th data by Ypma. Early quartz and late calcite-quartz gangue indicate T for main mineralization of 250-230°C, dropping to 150-80° in the late stages. Sulfides formed from moderately saline fluids (2-7 wt% NaCl eq.) at near-boiling conditions under 500-700 bars. No evidence for a T gradient between surface and 34 level, but salinity increases and CO_2 decreases with depth. (E.R.)

LONG, D.T., WILSON, T.P., TAKACS, M.J. and REZABEK, D.H., 1988, Stable-isotope geochemistry of saline near-surface ground water: East-central Michigan basin: Geol. Soc. Am. Bull., v. 100, p. 1568-1577. Authors at Dept. Geol. Sci., Michigan State Univ., East Lansing, MI 48824-1115.

Near-surface (<100 m) ground water in east-central Michigan basin is characterized by high total dissolved solids (100 to 53,000 mg/l). The source of the salinity and the cause of its distribution are unclear. The hypothesis investigated was that the source of the salinity is brines advecting or diffusing upward into near-surface meteoric water, and the cause of the salinity distribution is the slow flushing of water in the argillaceous sediments by recent meteoric water. $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$, ^{3}H, and selected geochemical variables were studied in the glacial-drift and bedrock aquifers composing the ground-water system.

The following isotopic ranges were found: $\delta^{18}O$, 6.93‰ to -18.46‰; δD, -47.3‰ to -137.4‰; $\delta^{13}C$, -6.26‰ to -20.65‰; and $\delta^{34}S$, +3.56‰ to +67.44‰. $\delta^{18}O$ and δD plot along the meteoric-water line, and most are extremely light. $\delta^{13}C$ is skewed to ligher values, and $\delta^{34}S$ becomes heavier with decreasing dissolved SO_4 concentration.

The results are intepreted to indicate that the saline ground water is a mix of modern-day, meteoric water and water that recharged the aquifers at a time when the climate was much cooler. The cause of the salinity distribution is the slow flushing of the aquifers by present-day recharge water. The source of the salinity could be the upward diffusion or advection of Michigan basin formation water, but this has not been confirmed. Microbial reduction of SO_4 is occurring, affecting the concentrations of SO_4 and HCO_3 and the values of $\delta^{13}C$ and $\delta^{34}S$. (Authors' abstract)

LOREDO, Jorge, LUQUE, Carlos and IGLESIAS, J.G., 1988, Conditions of formation of mercury deposits from the Cantabrian Zone (Spain): Bull. Minéral., v. 111, p. 393-400. First author at Escuela de Minas, Independencia 13, 33004 Oviedo, Spain.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 239. (H.E.B.)

LORENZ, J.C., FINLEY, S.J., and NORMAN, D.I., 1988, Tectonism, subsidence, and fracturing of Mesaverde Reservoirs in the Piceance Basin, Colorado (abst.): Am. Assoc. Petrol. Geol., v.72, no.2, p.215. Authors at New Mexico Inst. of Mining and Tech., Socorro, NM., USA.

Cretaceous strata in the Piceance basin of northwestern Colorado were subjected to several phases of tectonic, burial, and uplift stress. Isochore calculations indicate trapping P around 325 bars for fluid inclusions in 16 samples of quartz and calcite mineralization from the fractures, suggesting that mineralization occurred in a P-T regime compatible with the reconstructed burial depths of 10,000-12,000 ft. (From the authors' abstract)

LORIUS, C., BARKOV, N.I., JOUZEL, J., KOROTKEVICH, Y.S., KOTLYAKOV, V.M. and RAYNAUD, D., 1988, Antarctic ice core: CO_2 and climatic change over the last climatic cycle: Eos, v. 69, no. 26, p. 681, 683-684.

Based on the CO_2 of air inclusions in ice. (E.R.)

LOUCKS, R.R., 1988, Formation constants of aqueous cuprous chloride complexes to 250°C (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 58. Author at Dept. Earth & Atmos. Sci., Purdue Univ., West Lafayette, IN 47907, USA.

Published values of high-T (100-300°C) stability constants of chlorocopper (I) complexes currently in general use in hydrothermal geochemistry are very discrepant. However, several published data sets for solubility of CuCl in aqueous chloride media at 15-95°C are mutually consistent. Reliable equilibrium constants for $CuCl_c + nCl^- = CuCl^{n-}_{n+1}$ derived from solubility data were combined with determinations of the solubility product of $CuCl_c$ to 100°C based on consistent emf, solubility, and recent calorimetric data in order to derive experimentally based values of the formation constants β_n for $Cu^+ + nCl^- = CuCl^{n-1}_n$ at 15-95°C. These β's were combined with known β_n values of corresponding chlorosilver complexes to get log K_n

for exchange reactions of the type $AgCl_2^- + Cu^+ = Ag^+ + CuCl_2^-$, for which $\Delta C_p \approx 0$, so log K_n vs 1/T plots are linear and can be reliably extrapolated to higher T. Known values of $\beta_n(Ag)$ at high T are removed from extrapolated K_n values to recover predicted $\beta_n(Cu)$ to 250°C. The derived formation constants for chlorocopper (I) complexes are:

T°C	25	75	100	150	200	150
log β_1	3.26	3.02	2.95	2.92	3.08	---
log β_2	5.46	5.13	5.05	5.03	5.32	5.7
log β_3	4.79	4.12	3.91	3.59	3.63	---

(Author's abstract)

LOUCKS, R.R., LEMISH, John and DAMON, P.E., 1988, Polymetallic epithermal fissure vein mineralization, Topia, Durango, Mexico: Part I. District geology, geochronology, hydrothermal alteration, and vein mineralogy: Econ. Geol., v. 83, p. 1499-1528. First author at Ore Petrol-Geochem. Program, Dept. Earth & Atmosph. Sci., Purdue Univ., West Lafayette, IN 47907.

The Topia district [contains] a kilometer-thick sequence of early Tertiary andesitic lavas and pyroclastics resting on Mesozoic limestones and marine clastic sedimentary rocks. A set of faults was mineralized as Ag-Zn-Pb-Au-Cu-rich fissure veins.

Fissure-filling mineralization was accompanied by development of hydrothermal alteration comprising (1) a narrow (<1 m) quartz-sericite-pyrite alteration envelope (± adularia ± chamosite ± kaolinite ± hematite ± celadonite) that grades outward into (2) a variably silicified oxidative alteration zone that occupies the entire interval between veins at elevations in and above the ore horizon. The distal oxidative facies envelopes consist of an inner intense celadonite + quartz + hematite + calcite + illite + clinochlore subfacies and an outer subfacies of hematite + calcite veinlets in nearly fresh rock. At elevations below the ore horizon, the local oxidative alteration facies is absent and the inner silicification zone passes outward into conventional propylitic facies envelopes.

Open fissure intervals were filled by more or less symmetric, crustified precipitation on the walls, whereas wall-rock-replacement mineralization characterizes narrow veins in shear zone intervals. In each vein, ore occupies a restricted vertical interval of 100 to 200 m (the "ore horizon"), which grades downward into barren coarse-grained quartz-rich filling and grades upward into barren, cherty quartz-calcite-barite-rich vein filling. The ore horizon commonly contains subequal amounts of sphalerite, pyrite, galena, and quartz, with minor arsenopyrite, marcasite, chalcopyrite, Ag-rich sulfosalts, electrum, chamosite, muscovite, and carbonates. Locally, massive sphalerite as millimeter- to centimeter-thick crustification bands dominates the paragenetic sequence. Crustification bands dominated by quartz, calcite, and barite are predominantly fine grained; they precipitated from low-salinity, boiling fluids. Intercalated bands dominated by sulfides are characteristically very coarse grained (to 10 cm) and have high-salinity fluid inclusions (7-23 wt %); no P vapor-dominant inclusions have been recognized in sphalerite or pyrargyrite. Precipitation of crustification bands dominated by coarse-grained sulfides was punctuated by recurrent effervescence of ore fluids within the ore horizon, accompanied by precipitation of electrum + quartz ± calcite ± barite and dissolution of sphalerite. At currently exposed levels above the ore horizon, diluted fluids were boiling more or less continuously.

Fluid inclusion studies indicate ore deposition mainly in the 280° to 200°C interval, with a reasonably systematic vertical decrease in T of ~25°C/100 m. Direct analyses of fluid inclusions that trapped the liquid phase of vapor-saturated solutions yield CO_2 contents of 0.30 to 0.57 molal, increasing with depth. Fluid inclusion geobarometry is used (1) to show that regional tilting of the host andesites is preore, (2) to show that the 100- to 200-m-thick, districtwide ore shell formed at paleodepths ranging from about

500 to 1250 m, and (3) to constrain the amount of postore erosion preceding silicic ignimbrite eruptions at about 115 m. (From the author's abstract by E.R.)

LOWENSTEIN, T.K., 1988, Origin of depositional cycles in a Permian "saline giant:" The Salado (McNutt zone) evaporites of New Mexico and Texas: Geol. Soc. Am. Bull., v. 100, p. 592-608. Author at Dept. Geol. Sci. & Environ. Studies, SUNY, Binghamton, NY 13901.

Discusses the evidence derived from primary and secondary fluid inclusions in halite that bears on the origin of the Salado evaporite. (H.E.B.)

LOWENSTEIN, T.K., SPENCER, R.J. and ZHANG, Pengxi, 1988, Origin of ancient potash evaporites: Clues from the modern Qaidam Basin, western China (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A150. First author at Dept. Geol. Sci., S.U.N.Y. Binghamton, Binghamton, NY 13901.

The Qaidam Basin of western China (120,000 km^2) is a closed, non-marine basin that contains modern bedded potash salts. Carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) forms as an early diagenetic void-filling cement in Holocene-Pleistocene layered halite-siliciclastic sequences of Qarhan saline pan and forms a saline crust on the northern shore of Dabusun Lake (shallow perennial lake). The textures and timing of potash mineralization in modern and ancient deposits (for example, Permian Salado Formation of New Mexico) are similar.

Major sources of inflow to the Qarhan saline pan are Na-HCO_3-rich river waters and Na-Mg-Ca-Cl-rich spring waters. The spring inflow, which emerges at the surface along a fault-defined karst zone, may be a deeply-circulated hydrothermal water, due to its $CaCl_2$-rich composition (low SO_4^{-2} and mCa^{+2} greater than $mSO_4^{-2} + 1/2mHCO_3^{-} + mCO_3^{-2}$). Varying proportions of river inflow and spring inflow, syndepositional recycling of existing salts, and evaporative concentration, produce the varied chemical composition of the saline lakes of the Qarhan saline pan.

The melting behavior of fluid inclusions in halite from shallow core samples (0-13 m) from Qarhan saline pan provide data on Holocene-Pleistocene brine compositions. Holocene-Pleistocene brines are Na-Mg-Cl-rich (1.1-2.4 m Mg^{+2}, halite saturated) and fluctuate rapidly in concentration over short stratigraphic intervals. This is consistent with petrographic textures of halites that are diagnostic of precipitation in a shallow saline lake and saline pan setting. (Authors' abstract)

LU, H.-Z., 1988, Fluid inclusion studies on different types of Chinese gold deposits (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 442-444. Author at Sc. de la Terre, UQAC, Chicoutimi, PQ, Canada, G7H 2B1.

A brief review in which the chemical, Th, and isotopic data on Au deposits in PRC are categorized into types: stratabound, metamorphic hydrothermal, porphyry, migmatite, quartz vein associated with granite, and "Carlin type." (E.R.)

LU, H.-Z. and FANG, Genbao, 1988, The geological characteristics of Linglong gold deposits, China (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abstract Series, no. 23, p. 365-367. Authors at Sc. de la terre, UQAC, Chicoutimi, PQ, Canada, G7H 2B1.

The Linglong Au camp comprises more than 10 Au mines, which mostly occur in the Linglong migmatitic granites.

There are four mineralization stages (Table 1): milky quartz-pyrite, quartz-pyrite, quartz-base metal sulfides and carbonate. The ore minerals are native Au and pyrite. The stable isotopic data of (Pb, S, O and H) of these stages show that the mineralization was associated with the Linglong granites. Fluid inclusion studies indicate there are two types of inclusions: liquid-rich and CO_2 inclusions, with Th = 400-150°C and medium salinity. The Au mineralization is correlated with the content of CO_2 of fluids. The ore-forming fluids may be from the Linglong granites and mixture with the meteoric water. (From the authors' abstract by E.R.)

LUEDERS, Volker, 1988, Geochemical studies of the ores and ore minerals of the Harz Mountains: PhD dissertation, Berliner Geowis. Abh., Reihe A: Geol. & Paleo., v. 93, 74 pp (in German; English summary).

Indexed under "Fluid Inclusions." (E.R.)

LUNDEGARD, P.D. and KHARAKA, Y.K., 1988, Origin and significance of organic acid anions in subsurface waters (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). First author at Unocal Res., P.O. Box 76, Brea, CA 92621.

Integration of field observations, experimental data, and computer simulations provide valuable insights into the origin and inorganic interactions of high concentrations (<10,000 mg/L) of mono- and dicarboxylic acid anions and other reactive organic species present in formation waters from sedimentary basins. The original concentrations likely were higher because these organics are degraded by bacteria (t <80°C) and decarboxylated to CO_2 and natural gas thermally. Estimated field decarboxylation rates yield half-life values of 20 to 60 millon years at 100°C. The reported organic species are (1) important in carbonate diagenesis because they can control the pH, Eh, and buffer capacity of subsurface waters, (2) probably do not form strong complexes with Pb, Zn and U, and (3) play an important role in the geochemistry of Fe, Mn and possibly Al. Hydrous pyrolysis of sediments with different organic matter types show that (1) organic species in natural waters are produced by thermal degradation of kerogen, and (2) the organic generating capacities can vary by a factor of two or more in sediments from narrow stratigraphic intervals (<3 m). (Authors' abstract)

LYAKHOV, Yu.V., 1988, Thermobarogeochemistry of gold-ore associations of different depths, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 104-122 (in Russian).

LYONS, J.I., 1988, Geology and ore deposits of the Bolanos silver district, Jalisco, Mexico: Econ. Geol., v. 83, p. 1560-1582. Author at BP Minerals America, 4600 Kietzke Lane, Reno, NV 89502.

The Ag-rich veins of the Bolanos district, Jalisco, Mexico, are genetically related to a distinctive episode of gas-rich Sn-anomalous rhyolite magmatism. A contemporaneously developing fracture system served to localize the various ore deposits. The veins of Bolanos were emplaced in 600 m of welded rhyolite tuffs at the base of the exposed volcanic section. A propylitic halo to the mineralization is found to a limited extent in the 200 m of andesites and basalts overlying the ore host units. Weak hematitic fractures and silicified breccias are found in the 500 m of interbedded rhyolite flows and tuffs, and minor basalt flows at the top of the section. The mineralization closely followed or coincided with a episode of rhyolite magmatism that intruded mostly along northeast-trending faults and fractures. Gas-rich magmas vesiculated or otherwise degassed, resulting in the emplacement of intrusive tuff dikes and extensive sheets of open breccias along the structures. Metal-rich fluids invaded these breccias, resulting in high-grade veins and mineralized breccias with distinctively narrow alteration halos.

Throughout the district the ore deposits top out within a 150-m range in the stratigraphic section, from the top of the Bolanos tuff to the top of the Realito tuff. Although boiling has not been documented by fluid inclusion studies in the ore zone along the Bolanos vein, the uniformity of the tops of the system indicates dominant P-T controls on mineral deposition. Depending on the precise timing of mineralization, the field-indicated depth of mineralization could range from 200 to 600 m. Fluid inclusion studies on quartz and fluorite indicate ore deposition occurred in the range of 200° to 250°C from CO_2-rich fluids with salinities in the range of 8 to 16 eq wt % NaCl. (From the author's abstract by E.R.)

LYONS, J.I., 1988b, Volcanogenic iron oxide deposits, Cerro de Mercado and vicinity, Durango, Mexico: Econ. Geol., v. 83, p. 1886-1906. Author at 4240 Snowshoe Lane, Reno, NV 89502.

The Fe deposits of the Durango City, Mexico, area were formed by a variety of subaerial volcanic processes. The main deposit at Cerro de Mercado apparently resulted from the eruption of an Fe magma rich in F, Cl, CO_2, and water. Sheeted flows and flow breccias formed a volcanic dome above an intrusive feeder system. Fe oxides crystallized as magnetite, with abundant, clear, yellow-green apatite crystals forming concurrently in gas cavities and open breccias. Large volumes of halogen-rich gases streamed up through the Fe oxide flows and oxidized the magnetite to hematite (martite) and redeposited the Fe leached from the non-porous martite as laminated sandy magnetite in an extensive fumarolic blanket.

An immiscible Fe-rich volatile phase is believed to have evolved from the parent rhyolite magma by the introduction of CO_2 into the magma from carbonate wall rocks. This volatile-rich phase rose to the top of the magma chamber and up through the resurgent floor of the caldera. The fluid is believed to have boiled during its ascent, separating into vapor and liquid phases. At the magmatic T envisioned, water would disassociate and the O would combine with the Fe in the liquid phase to form a volatile-rich Fe oxide magma which was driven to the surface by a continuing stream of escaping gases. The H escaped in the vapor phase along with Cl and F, forming an intensely acid environment capable of carrying significant volumes of Fe in the form of Fe chloride vapors until reaching the atmosphere where the microcrystalline hematite powder was formed.

Comparison of Cerro de Mercado with other apatite-bearing, low titanium Fe deposits associated with silicic volcanic systems suggests that this volcanogenic model may be applicable to many of them. (From the author's abstract by E.R.)

LYONS, T.W., 1988, Color and fetidness in fine-grained carbonate rocks (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A211. Author at Dept. Geol. & Geophys., Yale Univ., New Haven, CT 06511.

Fetid (H_2S) odors associated with fracturing (as well as dilute, cold HCl digestion) and dark (fresh surface) colors are both common characteristics of carbonate rocks. These properties are, however, enigmatic. The Colina Limestone (Lower Permian) of southeastern Arizona, a micritic lagoonal Pedregosa basin unit, is a typical dark, fetid limestone. Analysis of a regional sampling of dark Colina lithologies (medium dark gray to grayish black) revealed a distinct paucity of total organic carbon (TOC), with a mean value of only 0.06%. These data, along with conodont (CAI) thermal studies in the region, suggest that dark gray to black colors in fine-grained limestones may be attributed to small quantities of thermally mature (highly carbonized) organic matter (OM). As a test of this hypothesis, samples of the Jurassic Solnhofen Limestone of West Germany, an anoxically-deposited anomalously light-colored unit, were heated in both open and sealed containers. Both sets of samples rapidly changed color, with the most dramatic change observed in the sealed vessel--from beige to dark gray. These samples contain only minor amounts of TOC. It appears that carbonization of small quantities of OM combined, perhaps, with manganese oxidation are able to impart dark colors in limestones. These findings have important implications concerning the use of color as an indicator of high TOC content and petroleum source potential.

Laboratory results indicate that Colina fetid odors represent liberation of H_2S trapped in inclusions and/or preserved micropores. Isotopic analysis of Colina H_2S suggests a closed-system, early-diagenetic origin for these gases. (Author's abstract)

McARTHUR, J.R., 1988, Fluid inclusion and stable isotopic studies on amethyst, Thunder Bay amethyst mine, Thunder Bay district, Ontario: BS thesis, Lakehead Univ., Thunder Bay, Ontario, 108 pp.

The Thunder Bay amethyst mine is composed of vein and breccia mineralization, containing amethyst, colorless quartz, prasiolite and citrine. The mine occurs in a strike-slip fault situated within a Archean batholitic intrusion of granodiorite.

During the present study fluid inclusions in amethyst indicated T on the order 60 to 90°C. Te values suggest the solution composition consisted of a $CaCl_2$ + NaCl system. Salinity of the solution decreases in the direction of vein growth from 22.9 to 15.3 eq. wt.% NaCl. The presence of Na in the system may assist in the production of hole and electron color centers by allowing for a charge compensation in the substitution of Fe^{3+} for Si^{4+} in the crystal lattice of quartz. Variations in salinity in the direction of growth may reflect changes in amethystine color density. Eh-pH conditions, calculated on the basis of paragenetic sequence within Cu-sulfide inclusions, suggest a reducing trend during deposition. Sulfur isotopic composition of pyrite in amethyst ($\delta^{34}S$ = -0.6 to -0.4) was compared to the sulfur isotopic composition of lead-zinc-barite veins in the Dorion area ($\delta^{34}S$ = -0.1). The similarity in isotopic signature suggest that both types of deposit have similar origin. (Author's abstract)

McARTHUR, J.R. and KISSIN, S.A., 1988, Stable isotope, fluid inclusion, and mineralogical studies relating to the genesis of amethyst, Thunder Bay amethyst mine, Ontario, Canada (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A40. Authors at Dept. Geol., Lakehead Univ., Thunder Bay, ON P7B 5E1 Canada.

The Thunder Bay Amethyst Mine exploits a vein system containing a zoned sequence of chalcedony, colorless to smoky quartz, and three distinct stages of amethyst. Included in the main vein sequence are brecciated fragments of an earlier sequence of chalcedony, colorless quartz, chalcedony, and two distinct stages of prasiolite. The vein system occupies a fault in Archean granodiorite and is associated with a narrow zone of sericitic alteration. Fragments of Proterozoic Sibley Group rocks occur in the veins indicating a shallow cover during vein formation.

Fluid inclusion Th are in the range 60 to 90°C, although inclusions in early colorless and smoky quartz homogenize at 135 to 146.5°C. Salinities decrease in the direction of growth from 22.9 to 15.3 eq. wt.% NaCl. Eutectic T fall into three ranges, -53.6 to -48.0°C, -46.7 to -44.5°C, and -44.5 to -41.1°C, which are related to paragenetic position and seem to indicate an NaCl-$CaCl_2$ system with increasing numbers of components such as Fe^{3+} and Zn^{2+}.

Continued next page.

Trace sulfide and other mineral inclusions indicate a trend of decreasing Eh and pH during deposition, starting with cuprite + hematite and culminating in covellite + pyrite. Sulphur isotopic composition in pyrite and chalcopyrite ranges from $\delta^{34}S$ = -0.4 to -1.4 per mil, and is similar to values obtained from Pb-Zn-barite veins in other deposits surrounding the Sibley depositional basin. Oxygen isotopes in quartz range from $\delta^{18}O$ = +12.7 to +17.1 per mil and are interpreted as derived from evolved basinal brines.

The amethyst deposits are believed to have formed from basinal brines expelled from Sibley Group sediments. The brines migrated through basin marginal faults and deposited amethyst due to cooling, due to mixing with meteoric water. T for amethyst formation and destruction appear to be much lower than suggested by previous experimental studies. (Authors' abstract)

McCAIG, A.M., 1988, Deep fluid circulation in fault zones: Geology, v. 16, p. 867-870.

McCLELLAND, J., HUNT, W.M. and HANSEN, E.C., 1988, The relationship between metamorphic charnockite and marble near Speculator, central Adirondack Mountains, New York: J. Geol., v. 96, p. 455-467. First author at Dept. Geol., Colgate Univ., Hamilton, NY 13346.

Granites and charnockites with similar bulk compositions are exposed in a series of roadcuts along Rt. 8-3 east of the central Adirondack town of Speculator. The mineralogy of these rocks is correlated with their associated rock types, with the orthopyroxene-bearing varieties occurring in the marble-rich portion of the sequence. Mineral assemblages in a charnockite boudin enclosed in marble appear to be consistent with equilibration with a CO_2-rich fluid under high-grade (T = 700°C, P = 7 kb) conditions, while high density, CO_2-rich fluid inclusions occur in a quartz vein enclosed within the boudin. It is suggested that small amounts of charnockite may have been produced in this area by the influx of CO_2 produced by devolatilization reactions in the marble. However, carbonic metamorphism in the Adirondacks appears to have been, at most, a minor local process and did not operate on the regional scale that has been suggested for some other granulite terranes. Thus, the presence of abundant carbonate stratigraphy in the Adirondacks did not give rise to pervasive CO_2 for regional metamorphism. (Authors' abstract)

McCUAIG, T.C., 1988, The Deadhorse Creek Zn-Pb-Ag veins and their relationship to other vein deposits of the Schreiber-Terrace Bay-Marathon region: BS thesis, Lakehead Univ., Thunder Bay, Ontario, 59 pp.

A reconnaissance of five Ag-bearing veins between Schreiber, Ontario, and Marathon, Ontario, indicate that the Pb-Zn-Ag veins in this area are genetically related. The three veins of this type that were studied (the Deadhorse Creek North, Deadhorse Creek South, and Morley High Grade veins) have very similar mineralogies with freibergite as the Ag-bearing phase. A general paragenetic sequence was noted, from early massive sphalerite ± pyrite to later massive galena + sphalerite ± chalcopyrite ± freibergite.

Fluid inclusion studies on these three veins indicate low to moderate T of formation (~160-355°C), low salinities, and some form of $NaCl-KCl-MgCl_2-H_2O$ fluid compositions. The veins are not, as previously suggested, related to intrusion of the Coldwell Alkaline Complex since one vein cuts the thermal aureole of the Complex and another is over 60 km away from it. The veins may, however, be rift related with much of the data presented here lending support to this hypothesis.

The other two veins studied are of indeterminate origin. They are not directly [related] genetically to the Pb-Zn-Ag veins since they have much different mineralogies. The Mogatherium vein contains a complex Cu-Pb-Bi-Te-Ag-S ore mineral assemblage, while only pyrite was found in the Gold Range samples analyzed. Fluid inclusion analysis yielded poor results for these veins and thus their mode of formation is still a point of conjecture. They may be related to the intrusion of the Terrace Bay Batholith, with which the veins are spatially associated. (Author's abstract)

McCUTCHEON, S.R. and ROBINSON, P.T., 1988a Chemical differences between quartz-hosted glass inclusions and their host rocks: Petrologic significance (abst.): GAC/MAC Program with Abstracts, v.13, p.A82. First author at Dept. of Natural Resources and Energy, Bathurst, New Brunswick E2A 3Z1.

Glass inclusions from felsic volcanic rocks of the late Devonian Piskahegan Group in southwestern New Brunswick are generally higher in Al_2O_3, Na_2O and to a lesser extent K_2O, but lower in SiO_2, TiO_2 and FeO_T than their host rocks. Glass inclusions from the Bishop Tuff in eastern California show similar chemical differences compared to <u>pristine</u> pumice samples. These differences between pumice and inclusions are a primary magmatic feature, and suggest that similar differences in the Piskahegan rocks may have a magmatic origin i.e. their bulk chemistry has not been significantly modified by post-eruptive processes.

These compositional differences are explained as follows: 1) The higher Al_2O_3, Na_2O and K_2O can be largely explained by <u>in situ</u> crystallization of phases that preceded quartz. These phases caused the remaining liquid to be enriched in SiO_2, Al_2O_3, Na_2O and K_2O. 2) The lower FeO_T and TiO_2 in the glass resulted from early crystallization of Fe-Ti oxides relative to quartz, thereby causing the remaining liquid to be depleted in these components. 3) The lower SiO_2 means that liquid boundary layers existed around quartz phenocrysts as they grew, and thus inclusions derived from these layers were less silica-rich than the bulk magma. (Authors' abstract)

McCUTCHEON, S.R. and ROBINSON, P.T., 1988b, Embayed volcanic quartz: A product of "cellular growth" rather than resorption (abst.): Maritime Sed. & Atlantic Geol., v. 24, no. 2, p. 203. First author at Dept. Natural Resources & Energy, Bathurst, New Brunswick, Canada.

See previous item. (E.R.)

McINNES, B.I.A., CROCKET, Jim and GOODFELLOW, W.D., 1988, Fluid inclusion and stable isotope studies of a Late Cretaceous epithermal gold deposit, Freegold Mountain, Dawson Range, Yukon, Canada (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 452-454. First author at Dept. Geol., Univ. Ottawa, Ottawa, Ontario, K1N 6N5.

Fluid inclusions from the 'deeper ore' zone have relatively narrow ranges of Th (175°-195°) and salinities (2 - 4.5 wt. % NaCl eq.). There are two types of inclusions, CO_2 vapor and H_2O liquid. The water has $\delta D = -130$ to $-150‰$ and a calculated $\delta^{18}O = -6.5$ to $-8‰$.

The middle part of the vein contains three types of inclusions, CO_2 vapor, H_2O with variable liquid/vapor ratios and H_2O liquid with one or more dms. This is interpreted to represent a 'true boiling zone' where H_2O liquid-vapor immiscibility has occurred. The extreme ranges in Th (165-430°C) and salinities (4-43 wt. % NaCl eq.) indicate that boiling of an original low salinity fluid has occurred in a 'closed' system where no additional fluid has diluted the saline brine. The fluids in the boiling zones have $\delta D = -105$ to $-54‰$ and $\delta^{18}O = -5.5$ to $-8‰$. (Continued)

The upper ore zone, 200 m above the boiling zone, has undergone multiple periods of brecciation and silicification. Some of the clasts within the vein breccia contain fluid inclusions with salinities, Th and dms similar to those found in the boiling zone. The vein breccia is interpreted to have formed by the explosive eruption of CO_2 and H_2O vapor trapped within the closed boiling system.

Other Au-bearing vein-breccia deposits at higher elevations have mineral assemblages of barite, stibnite, cinnabar, orpiment, Fe and Mn carbonates and chalcedonic silica. Fluid inclusions from these deposits have Th 140-185°C with salinities of 0-0.5 wt. % NaCl. The vein deposits at Freegold Mountain show marked similarities to precious metal deposits in New Zealand and western United States. (From the authors' abstract)

McKIBBEN, M.A., ANDES, J.P., Jr. and WILLIAMS, A.E., 1988, Active ore formation at a brine interface in metamorphosed deltaic lacustrine sediments: The Salton Sea geothermal system, California: Econ. Geol., v. 83, p. 511-523. First author at Tunell Econ. Geol. Lab., Dept. Earth Sci., & Geothermal Resources Program, Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 250-251, 1987. (E.R.)

McKIBBEN, M.A., ELDRIDGE, C.S. and WILLIAMS, A.E., 1988, Sulfur and base metal transport in the Salton Sea geothermal system: Geother. Resources Council, Transactions, v. 12, p. 121-125. First author at Geother. Res. Program, Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521, USA.

Sulfur isotope data demonstrate that H_2S in the SSGS brines is generated by partial hydrothermal reduction of SO_4^{2-} derived from dissolution of lacustrine sulfate minerals in the host sediments. No magmatic input of sulfur is indicated. SO_4^{2-} reduction is promoted by interaction of the sediments with an upwelling diapir of Fe^{2+}-rich hypersaline brine. Base metals are carried in the brines as the chloride complexes $PbCl_3^-$, $ZnCl_2^o$, $CdCl_2^o$, $CuCl_3^{2-}$, and $MnCl_2^o$. Fe is probably carried as both $FeCl_3^-$ and $FeCl_4^-$ complexes. Vein sulfide precipitation within the reservoir occurs during brine dilution and oxidation at an interface between the hypersaline brines and overlying, more oxidized lower-salinity fluids. (Authors' abstract)

McKIBBEN, Michael and WILLIAMS, Aland, 1988, Metal chloride speciation in saline hydrothermal fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A98. Authors at Dept. Earth Sci. & Geothermal Resources Program IGPP, Univ. Calif., Riverside, CA 92521.

Few data exist on the speciation and thermodynamics of metal chloride complexes in saline fluids at elevated T. Experimental data are generally derived for simple systems at < 3 m NaCl, and theoretical calculations of speciation often are based on extrapolation of data from lower-salinity solutions and/or lower T. Therefore, it is desirable to determine and test such information empirically whenever possible using data from active geothermal systems.

Our database from the Salton Sea geothermal system includes a series of 44 nearly isothermal (≈300°C) Na-Ca-K-Cl brine analyses covering a range of total chloride concentrations from 3-6 molal. In such brines only 4-9 water molecules exist per ion, and the low dielectric constant of water further reduces the degree of ionization. Consequently, the predominant metal chloride species in these brines should be neutral or high ligand number chloride complexes.

Published thermodynamic data on alkali chloride solutions indicate that activity coefficients remain relatively constant at high salinities at elevated T. Therefore, isothermal plots of log total metal molality versus log total chloride molality will yield slopes corresponding to the mean ligand number of the metal chloride complexes, assuming that a single mineral controls a given metal's solubility and that pH and mH_2S remain relatively constant over the salinity range.

From such plots we have determined the mean ligand numbers for several metal chloride complexes in the Salton Sea brines. For Pb, our data yield a mean ligand number of 2.8, in excellent agreement with trends expected from the lower-salinity experimental data of Seward (1984). For Zn, our data yield a mean ligand number of 2.0, again in excellent agreement with the lower-salinity data of Ruaya & Seward (1986) and Bourcier & Barnes (1987). Our determinations for several metals indicate that the dominant chloride complexes at 300°C and 3-6 molal Cl are: $PbCl_3^-$, $ZnCl_2^\circ$, $Cd\,Cl_2^\circ$, $CuCl_3^{2-}$, and $MnCl_2^\circ$. Fe data are complicated by the presence of both Fe^{2+} and Fe^{3+} in the brines, yielding a mean ligand number of 4.4.

These empirical data should serve as guides for future experiments and can help constrain theoretical calculations of speciation in saline hydrothermal fluids, allowing more accurate modeling of ore-forming processes. (Authors' abstract)

McKIBBEN, M.A., WILLIAMS, A.E., and OKUBO, Susumu, 1988, Metamorphosed Plio-Pleistocene evaporites and the origins of hypersaline brines in the Salton Sea geothermal system, California: Fluid inclusion evidence: Geochim. Cosmo. Acta, v.52, p.1047-1056. First author at Tunell Econ. Geo. Lab., Dept. of Earth Sci., Univ. of California, Riverside, CA 92521, USA.

The Salton Sea geothermal system (SSGS) occurs in Plio-Pleistocene deltaic-lacustrine-evaporite sediments deposited in the Salton Trough, an active continental rift zone. T up to 365°C and hypersaline brines with up to 26 wt.% TDS are encountered at 1-3 km depth in the sediments, which are undergoing active greenschist facies hydrothermal metamorphism. Previous models for the origins of the Na-Ca-K-Cl brines have assumed that the high salinities were derived mainly from the downward percolation of cold, dense brines formed by low-T dissolution of shallow non-marine evaporites.

New drillcores from the central part of the geothermal field contain metamorphosed, bedded evaporites at 1 km depth consisting largely of hornfelsic anhydrite interbedded with anhydrite-cemented solution-collapse shale breccias. Fluid inclusions trapped within the bedded and breccia-cementing anhydrite have Th 300°C (identical to the measured downhole T) and contain saline Na-Ca-K-Cl brines. Some of the inclusions contain up to 50 vol.% halite, sylvite and carbonate crystals at room T, and some halite crystals persist to above 300°C upon laboratory heating. The data are consistent with the trapping of halite-saturated Na-Ca-K-Cl fluids during hydrothermal metamorphism of the evaporites and accompanying solution collapse of interbedded shales. We conclude that many of the salt crystals in inclusions are the residuum of bedded evaporitic salt that was dissolved during metamorphism by heated connate fluids.

Therefore, the high salinities of the Salton Sea geothermal brines are derived in part from the in situ hydrothermal metamorphism and dissolution of halides and $CaSO_4$ from relatively deeply-buried lacustrine evaporites. This fact places important constraints on modeling fluid-flow in the SSGS, as brines need not have migrated over great distances. The brines have been further modified to their present complex Na-Ca-K-Fe-Mn-Cl compositions by on-going sediment metamorphism and water-rock interaction. (Authors' abstract)

McLAREN, Alex, GERRETSEN, Jurriaan, and FITZGERALD, John, 1988, Dislocation nucleation mechanisms in wet synthetic quartz (abst.): EOS, v.69, p.266. First author at Research School of Earth Sci., Australian Nat'l Univ.

Dislocation nucleation in wet synthetic quartz has been studied by TEM in a series of specimens cut from the same growth region of crystal W2. Fresh dislocations nucleated as a result of heat-treatment and/or stress were observed only in "wet" bands (C_{H_2O}=1000H/10^6Si) which initially contain high P inclusions (water clusters). Three mechanisms of nucleation were observed:(i) On heating at atmospheric P and a T in excess of 825 K, sessile edge dislocation loops ($\underline{b}$=a<$11\bar{2}0$>) linked to strain free inclusions (bubbles), are nucleated and grow by climb to reduce the P in the clusters (ii). Under the same conditions, some clusters are modified to features consisting of a single bubble attached to a disk shaped defect which appears to be a microcrack lying parallel to r($10\bar{1}1$). (From authors' abstract)

McLELLAND, J., HUNT, W.M. and HANSEN, E.C., 1988, The relationship between metamorphic charnockite and marble near Speculator, central Adirondack Mountains, New York: J. Geol., v. 96, p. 455-467. First author at Dept. Geol., Colgate Univ., Hamilton, NY 13346.

Granites and charnockites with similar bulk compositions are exposed in a series of roadcuts along Rt. 8-3 east of the central Adirondack town of Speculator. The mineralogy of these rocks is correlated with their associated rock types, with the orthopyroxene-bearing varieties occurring in the marble-rich portion of the sequence. Mineral assemblages in a charnockite boudin enclosed in marble appear to be consistent with equilibration with a CO_2-rich fluid under high-grade (T = 700°C, P = 7 kb) conditions, while high density, CO_2-rich fluid inclusions occur in a quartz vein enclosed within the boudin. It is suggested that small amounts of charnockite may have been produced in this area by the influx of CO_2 produced by devolatilization reactions in the marble. However, carbonic metamorphism in the Adirondacks appears to have been, at most, a minor local process and did not operate on the regional scale that has been suggested for some other granulite terranes. Thus, the presence of abundant carbonate stratigraphy in the Adirondacks did not give rise to pervasive CO_2 for regional metamorphism. (Authors' abstract)

McLIMANS, R.K. and VIDETICH, P.E., 1987, Reservoir diagenesis and oil migration: Middle Jurassic Great Oolite Limestone of Wealden Basin, southern England: Petroleum Geol. of North West Europe, Vol. 1, J. Brooks and K. Glennie, eds. (Graham & Trotman London), p. 119-128. First author at Conoco (UK) Ltd., Park House, 116 Park St., London W1, UK.

The Middle Jurassic Great Oolite Limestone of the Wealden Basin, southern England, is a target of active exploration owing to such recent discoveries of oil as the Conoco discovery at the Storrington-1 location.

Throughout the basin, similar lithologies in the Great Oolite have porosities ranging from less than 5% to greater than 20%. Hence, the principal control on porosity preservation is diagenetic history. In the Storrington-1 production interval, the high porosity resulted from early mineralogical stabilization of limestones in a mixing-zone between fresh water and marine phreatic environments.

Extensive occlusion of porosity is by coarse calcite spar cement. Studies of aqueous fluid inclusions in those cements indicate a deep burial origin followed by uplift. Oil-filled fluid inclusions also occur in calcite spar cements, indicating that oil was in a mobile phase at the time of cementation. Reconstruction of basin structure and maturation modelling show that cementation-oil migration was in the Cretaceous. That, together with the distribution of oil-filled inclusions, indicates that migration and accumulation of oil was mainly in the west-south-western parts of the basin. (Authors' abstract)

McQUEEN, K.G. and BOX, Sara, 1988, Mineralization at the Wallah Wallah silver mine, Rye Park, New South Wales and its metallogenic significance: Mineral. & Petrol., v. 39, p. 289-305. Authors at Sch. Appl. Sci., Canberra College Adv. Ed., Belconnen, Australia.

The Wallah Wallah Pb-Zn-Ag deposit near Rye Park, New South Wales, Australia, consists of epigenetic, vein-type mineralization developed in deformed Ordovician host rocks by deposition from medium T (280-380°C), low salinity fluids. [FI microthermometric data.] (From the authors' abstract by H.E.B.)

McSWEEN, H.Y., Jr. and KITTLESON, R.C., 1988, Comparison of Archean and Phanerozoic granulites; southern India and North American Appalachians: Workshop on the Deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 98-100. (Also in J. Geol. Soc. India, v. 31, no. 1, p. 74-77.)

Indexed under "Fluid Inclusions." (E.R.)

MÄDER, U.K., BERMAN, R.G. and GREENWOOD, H.J., 1988, An equation of state for carbon dioxide consistent with phase equilibrium data: 400-2000 K, 1 bar-50 kbar (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A190. First author at Dept. Geol. Sci., UBC, Vancouver, V6T 2B4, Canada.

Existing equations of state for carbon dioxide (Kerrick & Jacobs, 1981; Bottinga & Richet, 1981) are based on PVT data only and lead to significant deviations from phase equilibrium data at P greater than 10 kbar.

Mathematical programming analysis provides a method whereby adjustable equation of state parameters can be fitted using constraints from both phase equilibrium and PVT data simultaneously. Phase equilibrium data (ca. 130 half-brackets up to 45 kbar) are used to define a feasible region for the adjustable parameters in free energy (RT log fCO_2) space. A nonlinear 'least squares' objective function is used to optimize parameters to the PVT data (ca. 600 measurements up to 8 kbar). Thermochemical data of solid phases were taken from the mineral data base of Berman (J. Pet., 1988) which includes expansivity and compressibility terms.

A Van-der-Waals type equation of state with five adjustable parameters has been developed for carbon dioxide. The function is smooth and continuous above the critical region, behaves well in the high and low P limits, and the calculation of $\int V\,dP$ for free energy does not require numerical integration. These properties allow for meaningful extrapolation (100 kbar) and easy use in phase equilibrium calculations. The derived equation of state parameters yield free energies consistent with almost all phase equilibrium data and computed volumes agree within the uncertainties of PVT measurements. In the following equation of state, B_1, B_2, B_3, A_1, A_2 are the adjustable parameters and R is the gas constant. (Authors' abstract)

$$P = \frac{RT}{V-b} - \frac{A_1}{TV^2} + \frac{A_2}{V^4} \; ; \; b = B_1 + B_2T - \frac{B_3}{V^3 + C} \; ; \; C = \frac{B_3}{B_1 + B_2T}$$

MAKHMUDOV, B.R., 1987, Thermobarogeochemical zoning in gold ore deposit of central Asia [USSR]: Mineral. Assots. Mestorozhd. Tsv. i Blagorod. Met. Sred. Azii, Tashkent 1987, p.46-58 (in Russian). From Ref. Zh., Geol. 1988, Abstr. No. 5D26.

MAMEDOV, A.I., 1987, Liquation in acidic lavas: Vopr. Geol. Petrol. Azerbaidzhana, Baku 1987, p. 112-118 (in Russian). From Ref. Zh., Geol. 1988, Abstr. No. 3V344.

MANGAS, J. and ARRIBAS, A., 1988a Hydrothermal fluid evolution of the Sn-W mineralization in the Parrilla ore deposit (Cáceres, Spain): J. Geol. Soc., London, v. 145, p. 147-155.

This is the full paper for abstract in Fluid Inclusion Research, v. 19, p. 280. (E.R.)

MANGAS, Jose and ARRIBAS, Antonio, 1988b Evolution of hydrothermal fluids in the Feli tin deposit, western Spain: Bull. Minéral., v. 111, p. 343-358. First author at Dept. Geol., Fac. Ciencias del Mar, Univ. Politécnica de Canarias, Apdo, 550, Las Palmas, Spain.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 254-255. (H.E.B.)

MANGO, Helen, ZANTOP, Half, CHAMBERLAIN, Page and BARREIRO, Barbara, 1988, A fluid inclusion and isotope study of the Las Rayas Ag-Au-Pb-Cu mine, Guanajuato, Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A37. Authors at Dept. Earth Sci., Dartmouth College, Hanover, NH 03755.

FI and stable isotope analyses from the Las Rayas Ag-Au-Pb-Cu deposit indicate that dilution of hot, saline, metal-bearing hydrothermal fluids by cool, nonsaline meteoric water caused the deposition of Ag, Au and base-metal sulfides. The environment was moderately hot (270°C) and the solutions of low salinity (<1 wt.% NaCl eq.) and mild alkalinity. FI have constant liquid-to-vapor ratios, indicating the absence of boiling in the system. T and salinity decreases toward the surface point to dilution. This is supported by oxygen isotope data suggesting mixing of meteoric water with a minor magmatic component, or its interaction with country rock. The interpretation of ore formation by dilution in the Las Rayas mine differs from previous interpretations elsewhere in the district, which held boiling responsible for metal precipitation. FI gas analysis indicates large amounts of H_2S, making the solutions effective carriers of Au. Since there is little Au in Las Rayas, it may have precipitated at a higher, boiling, level as occurs elsewhere in the district. The depositional environment at Las Rayas favored precipitation of Ag- and base-metal sulfides from chloride complexes. Pb isotopic values indicate a single crustal source for the metals, an interpretation supported by carbon isotope data. Las Rayas may represent the bottom of a vertical sequence of ore zones, with base-metal-rich and Ag mineralization at the bottom and a possibly eroded Au-rich zone at the top. (Authors' abstract)

MANGOLD, Matthias, 1988, On microthermometry and geochemistry of fluorite in Sarrabus-Gerrei (SE Sardinia) as an indicator of ore-forming processes: Berliner geowiss, Abh. Reihe A, v. 92, 74 pp. (in German; English summary).

Beneath other deposits a large number of fluorite-barite (F-Ba) mineralizations occur in this region which can be distinguished in a) discordant vein-type deposits with steep dipping, and b) stratabound deposits with stratiform or sheetlike character and redeposition.

The discordant veins have barite, fluorite, calcite resp. dolomite, quartz and minor amounts of sulfides like pyrite, galena, sphalerite. The stratabound mineralizations occur as gangue-minerals like fluorite, barite, calcite accompanying the ore deposits of the so-called "Filone Argentifero," which is hosted in graphitic black shales with intercalated carbonate rocks of the Silurian-Devonian Monte Narba Formation.

Geochemical investigations of the rare earth elements (REE) as well as microthermometric measurements on fluorite show that the F-Ba mineralization is a product of a multiphase hydrothermal process and the fluorite occurring today is characterized by redeposition. Only one mineralization (Tertiary age) shows the typical behavior of a P crystallization (Monte Cardiga).

According to fluid inclusions they can be divided into three different groups: Regime I has a salinity of 20% NaCl eq with Th from 70 to 300°C; Regime II (subordinate to I) has a salinity of 30% $CaCl_2$ eq with Th from 70 to 130°C; and Regime III (even subordinate to I) has a salinity of 5-8% NaCl eq with Th from 90 to 280°C. [The study suggests] a redeposition of older F-Ba mineralization under hydrothermal conditions. (From the author's Summary by E.R.)

MANIER-GLAVINAZ, V., COUTY, R. and LAGACHE, M., 1988, Experimental study of the equilibrium between a natural beryl and hydrothermal fluids, geochemical inferences (abst.): Chem. Geol., v. 70, p. 162. Authors at Lab. Géol. l'Ecole Normale Supérieure, 24 rue Lhomond, Paris 5, France.

Alkali-rich beryls occurring in rare element bearing pegmatites contain Li, Na and Cs in large amounts. The composition of beryls is very sensitive to the geochemistry of their parent pegmatites. In order to precise the relations existing between the alkaline composition of beryls and that of the mineralizing solution, two types of experiments on a natural beryl at 600°C and 1.5 kbar have been carried out.

- Beryl + chloride solutions of Li, Na or Cs: Beryl is enriched in the alkali element present in the solution and impoverished in the two others. For Li, there is no apparent limit of saturation. The enrichment in Na is quickly accompanied by the crystallization of albite. The pollucite crystallizes after the saturation in Cs has been reached. Be is not involved in these experiments. There is a correlation between the ratio R/(Li + Na + Cs) in the solid phase and in the solution (R ≈ Li, Na or Cs) which allows us to approach the relative alkaline compostion of the mineralizing fluid of a given beryl.
- Beryl + HCl solutions: The three alkali elements come out and the leaching depends on the chloride concentration of the solution. Be is not involved in these experiments. The infrared spectra realized on beryls at different steps of leaching show: in the channels: disappearence of the $H_2O(I)$ and decreasing of the R-OH frequencies while a new frequency (3705 cm^{-1}) attributed to H(channel) - O(network) increases. In the network: reorganization of the structure of beryl becoming analogous to that of a pure synthetic beryl. (Authors' abstract)

MANNING, D.A.C. and PICHAVANT, M., 1988, Volatiles and their bearing on the behavior of metals in granitic systems, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 13-24.

MANOKHIN, A.I., UGLOV, A.A. and GNEDOVETS, A.G., 1988, Kinetics of evaporation and vapor condensation on a droplet. Role of Knudsen's layer in a continuous medium regime: Dokl. Akad. Nauk SSSR, v. 298, no. 2, p. 357-360 (in Russian). Author at Inst. Metallurgy of Acad. Sci. USSR, Moscow, USSR.

The paper discusses distribution of T and P in the boundary layer between gas and liquid of thickness comparable to the mean free path of a molecule, useful for the evaporation/condensation studies in fluid inclusions. (A.K.)

MANSKE, S.L., MATLACK, W.F., SPRINGETT, M.W., STRAKELE, A.E., Jr., WATOWICH, S.N., YEOMANS, B. and YEOMANS, E., 1988, Geology of the Mesquite deposit, Imperial County, California: Mining Engrg., v. 40, no. 6, p. 439-444. Indexed under "Fluid Inclusions." (E.R.)

MAO, Dongqing, LU, Huanzhang and FANG, Genbao, 1988, Melt inclusions in basalts of Ross Island area, Antarctica: Geochemistry (Chinese J.), v. 7, no. 1, p. 46-56; also Acta petrologica Sinica, 1988 no. 1, p. 48-58 (in Chinese; English abstract). First author at Inst. Gold Research, Shenyang.

There are many melt and fluid inclusions (mainly CO_2-rich) in olivine and pyroxene phenocrysts in basalts from the Ross Island area. The melt inclusions can be classified as follows: (1) crystalline melt inclusions (type I), (2) fluid-melt inclusions (type II) and (3) glass inclusions (type III). The dms in type I include olivine, plagioclase, ilmenite, etc. Fluid-melt inclusions are a new type which represent immiscibility of magma and fluid at a particular stage of evolution. Three types of fluid-melt inclusions were examined in this study: a) crystal + liquid + gas, b) inclusions coexisting with glass inclusions and fluid inclusions, and c) crystal + dm (dissolved salt) + gas. Both P and S melt inclusions are recognizable in the samples. The S melt inclusions were formed during healing of fractures in the host minerals in the process of magma rise.

Th (both Leitz 1350 stage and quench method were used) of melt inclusions in basalts range from 1190 to 1350°C at [sic] high P (about 7 kbars), indicating that the basalts may have come from the upper mantle. Melt-fluid immiscibility in basaltic magma shows that the CO_2-rich fluids may be the main fluid phase in the upper mantle, which is of significance in understanding the evolution of magma and various processes in the deep levels of the earth.

Th of melt and aqueous fluid inclusions in granites and metamorphic rocks in this area vary from 980 to 1100°C and 279 to 350°C, respectively. (Authors' abstract)

MARIGNAC, Christian, 1988a, Fluid phase evolution determined from mineral compositions: Example of the polymetallic ore veins at Aïn Barbar (Algeria): Bull. Minéral., v. 111, p. 183-206 (in French). Author at E.M.N., Parc de Saurupt, 54042 Nancy Cedex & C.R.P.G., rue N.D. des Pauvres, B.P. 20, 54501 Vandoeuvre, France.

This and the following item represent the full report for an abstract in Fluid Inclusion Research, v. 20, p. 257-258. (E.R.)

MARIGNAC, Christian, 1988b, P-T-X evolution of ore veins associated with palaeogeothermal activity at Aïn Barbar (NE Konstantine, Algeria): Reconstruction from fluid inclusion data: Bull. Minéral., v. 111, p.359-381. Author at Ecole des Mines de Nancy, Parc de Saurupt, 54042 Nancy Cedex, France.

This and the previous item represent the full paper of abstract in Fluid Inclusion Research, v. 20, p. 257-258. (H.E.B.)

MARSHALL, D.J., ed., 1988 Cathodoluminescence of geological materials: Publ., Unwin Hyman, 1988, ISBN 0-04-522026-7, 146 pp.

Of pertinence in recognizing growth stages in some minerals. (E.R.)

MARTIN, R.F. and MOROGAN, Viorica, 1988, Partial melting of fenitized crustal zenoliths in the Oldoinyo Lengai carbonatitic volcano, Tanzania: Reply: Am. Mineral., v. 73, p. 1468-1471. First author at Dept. Geol.

Sci., McGill Univ., 3450 University St., Montreal, Quebec H3A 2A7, Canada.

There is perhaps no more exotic an igneous rock type than natrocarbonatite, erupted from the volcano Oldoinyo Lengai, in northern Tanzania. Its origin is still the object of debate. Gittins (1988)* has proposed that the alkalic carbonatite magma is a relatively evolved derivative of a mantle-derived olivine-bearing sövite. We agree that it is geochemically an evolved magma, as are the associated silicate lavas; however, the bulk of the evidence suggests to us that the natrocarbonatitic magma has a crustal component and may well have formed within the crust. In this essay, we review the background information pertinent to this proposal, made in our paper on xenoliths of fenitized crustal material brought up in the natrocarbonatite lava (Morogan and Martin, 1985). (Authors' abstract)

*See Gittins (1988), this volume. (E.R.)

MARTY, B. and JAMBON, A., 1988, Volatiles in magma: The He-CO_2 relationship (abst.): Kagoshima Int'l. Conf. on Volcanoes Abstracts, p. 294.

The role of volatiles in magmas has recently gained a revival with the study of noble gases, for which the geochemical history and present flux are well constrained. Hence, further information concerning major volatiles (e.g., CO_2, H_2O, ΣS) may be derived if the respective behavior and mole balance of major and trace gases during igneous processes could be understood.

We have investigated the relative proportions of He and CO_2 and isotope ratios of He and C in various samples:

1. MORB glasses - These lavas usually contain vesicles filled with almost pure CO_2. In typical MORB's ($^3He/^4He \simeq 1.1 \pm 0.15 \times 10^{-8}$), the $CO_2/^3He$ molar ratio shows little variation in both the vesicle component and the dissolved component around 2×10^9. This characteristic is regarded as reflecting the fact that CO_2 and He solubilities in basaltic melts are similar and that the above cited ratio reflects a worldwide homogeneity. We can therefore derive a CO_2 flux from depth of 2.1×10^{12} mol/yr, considering the ^3He primordial flux of 4 atom/cm^2s. This flux is lower than previous estimates and argues against a massive recycling of C (and other volatiles?) in subduction areas. Hence subducted material needs to be stored or outgassed in the subduction zone rather than reinjected into the mantle.

2. Volcanic and geothermal gases from arcs (Japan, Italy) and a hot spot area (Hengill, Iceland) - $^3He/^4He$ trends in 13 volcanic sites of Japan are interpreted as reflecting the magma generation at arcs, the interaction with the crust and the volcanic activity. $CO_2/^3He$ ratios at arcs are about one order of magnitude higher than in MORB. This difference may result from: (i) a crustal contribution in the volcano area; or (ii) the addition of 1 ~ 2% subducted sediments to the source of magmas. We favor the second possibility as it agrees well with other chemical tracers (^{10}Be, trace elements, Sr, Nd, Pb ratios). (Authors' abstract)

MÂRZA, Ioan, POMÂRLEANU, Vasile and POMÂRLEANU, Eleonora-Ana, 1986, The quartz lode located in the striped clays at Luna de Sus (Cluj County): Studia Univ. Babes-Bolyai, Geologia-Geographia, v. 31, no. 1, p. 3-8 (in French; English abstract). First author at Univ. Cluj-Napoca, Chaire de géol.-minéral., 3400 Cluj-Napoca, 1 rue M. Kogainiceanu, Romania.

A quartz lode located in the Eocene stripe of the Sarata Valley (Luna de Sus, Cluj County) was studied. As we stated this lode is genetically associated with the Laramic magmatics. The geothermometrical analysis shows two crystallization domains: between 174-235°C (the main crystallization phase - indicated by P inclusions) and 140-146°C (S inclusions).

These on the surface mineralization signs certify the in-depth possible presence of metallic sulfides. (Authors' abstract)

MAS, G.R. and PERAL, H.R., 1988, A mineralogical study and characteristics of the fluid inclusions in topaz from Tanti: Asoc. Geol. Argentina, v. 42 (3-4), p. 429-440 (in Spanish; English abstract).

The mineralogical properties of the topaz from the Tanti pegmatite, Cordoba, have been studied by means of petrographic microscopy, X-ray diffractometry, infrared spectroscopy, chemical analyses, etc.

There have been studies also the fluid inclusions present in the mineral, the number and kind of phases, Th and P and the relationship between F/OH and the physical-chemical conditions of crystallization. (Authors' abstract)

MASHEDER, R. and RANKIN, A.H., 1988, Fluid inclusion studies on the Ecton Hill copper deposits, north Staffordshire: Mineral. Mag., v. 52, p. 473-482. Authors at Mining Geol. Div., Royal Sch. Mines, Imperial College, London SW7 2BP, UK.

Thermometric and D-ICP analysis of fluid inclusions in calcite and fluorite show that the fluids responsible for extensive carbonate-hosted copper mineralization in the Ecton Hill area are low-T (<100°C), high-salinity (19.5 to 23 wt.% NaCl eq.) brines strongly enriched in calcium (mean Ca:Na wt. ratio = 1.9). Compared with the fluids responsible for classical 'Mississippi Valley type' Pb-Zn deposits elsewhere in the south Pennine ore field, the Ecton ore-fluids were of lower T and slightly more enriched in potassium. Despite these subtle differences, the data are consistent with a basinal brine model for ore genesis in this western part of the ore field similar to that envisaged for the remainder of the ore field. These Ca-Na-K-Cl, copper-bearing brines were most probably derived from the Cheshire basin located to the west of the Derbyshire Dome. (Authors' abstract)

MASON, Robert, 1988, Felsic magmatism and hydrothermal gold deposits; a tectonic perspective: 8th Int'l. Conf. on basement tectonics; characterization and comparison of Precambrian through Mesozoic continental margins; Program with Abstracts, Butte, MT, USA, Aug. 8-12, 1988, Proc. Int'l. Conf. on Basement Tectonics, v. 8, p. 27.

Indexed under "Fluid Inclusions." (E.R.)

MASSARE, D., SYFOSSE,G. and CLOCCHIATTI, R., 1988, Optical observation and measurement of $\alpha \rightarrow \beta$ temperature inversion in quartz rhyolitic phenocrysts under hydrostatic pressure (20 to 470 MPa): C.R. Acad. Sci. Paris, v. 307, Sèrie II, p. 375-378 (in French; English abstract).

In rhyolitic quartz phenocrysts, experimental $\alpha \rightarrow \beta$ inversion leads to adjustment of the previous cracks of thermal origin. This phenomenon can be observed in phenocrysts put in an internally heated autoclave fitted with sapphire windows. It shows that the change in $\alpha \rightarrow \beta$ inversion T between 20 and 470 MPa, is linear. The measured dT/dP (0.25) is in good agreement with values (0.15 to 0.29) given by other methods. The $\alpha \rightarrow \beta$ inversion in quartz is also used as an internal standard of T. (Authors' abstract)

MATSUHISA, Y., HEDENQUIST, J.W., IZAWA, E., MARUMO, K., SASAKI, A. and AOKI, M., 1988 Ore fluids for gold mineralization of acid-leached siliceous rocks in the Nansatsu district (abst.): Mining Geol., v. 38, no. 1, p. 78 (in Japanese).

MATTER, A., PETERS, Tj., BLÄSI, H.R., MEYER, J., ISCHI, H. and MEYER, Ch., 1988, The Weiach exploration borehole. Geology. 438 pages with an extensive appendix: "Fluid Inclusions" by Mullis, J. and Meyer, J., p.359-370, appendices 7.24, 7.25 and 7.26 (in German): Geologische Berichte der (Schweizerischen) Landeshydrologie und -Geologie. [Geological Reports of the National Survey of Hydrology and Geology (from Switzerland)], 1988, no. 6, (in German).

MATTER, A., PETERS, Tj., BLÄSI, H.R., SCHENKER, F. and WEISS, H.P., 1988, The Schafisheim exploration borehole. Geology. 321 pages with an extensive appendix: "Fluid Inclusions" by Mullis, J., p. 253-358, appendix 7.20 (in German): Geologische Berichte der (Schweizerischen) Landeshydrologie und -Geologie. [Geological Reports of the National Survey of Hydrology and Geology (from Switzerland)], 1988, no. 8, (in German).

MATTEY, D.P., EXLEY, R.A. and PILLINGER, C.T., 1988, Carbon isotopic composition of coexisting fluid and dissolved species in basalt glass (abst.): Chem. Geol., v. 70, p. 11. First author at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK.

The isotopic composition of coexisting fluid and dissolved carbon species in basalt glass have been determined using a combination of replicate stepped heating experiments, vacuum crushing and grain-size analysis techniques. Replicate analyses of a pristine glass sample show that chemical precleaning of the sample can remove up to 95% of the surficial organic contamination derived through atmospheric exposure. Lowest abundances of low-T carbon (LTC) are obtained when samples are ultrasonically cleaned briefly in dichloromethane then immediately loaded into the vacuum system; combustion at 400°C and 600°C ensures complete removal of contamination prior to extraction of high-T carbon(HTC) species above 600°C. Replicate analyses indicate that HTC abundances vary by up to 30%, reflecting significant heterogeneity on a mm scale, whereas $\delta^{13}C$ values of HTC analyzed in >1 mm size chips can be reproduced to within better than ± 0.5% . The results of combined vacuum crushing/grain-size analysis/stepped heating suggest that CO_2 released at 800°C tends to be derived from vesicles whereas CO_2 released at 1200°C represents CO_3^{2-} dissolved in the glass. Using stepped heatng data to resolve HTC into the two principle coexisting magmatic carbon components these data can be used to place limits on the magnitude of carbon isotopic fractionation between CO_2 and natural basaltic melts at quench T. αCO_2-(basalt melt) values of ≈ 2‰ are suggested by the dataset, i.e., less than half the value of 4.4‰ determined experimentally for αCO_2-(basalt melt) by Javoy et al. (1977). As most submarine basalts appear to have undergone near-equilibrium outgassing of CO_2, αCO_2-(basalt melt) values of 2‰ imply that measured $\delta^{13}C$ values for HTC may closely reflect the $\delta^{13}C$ of mantle source regions. (Authors' abstract)

MATVIENKO, A.D., 1988, The indicator value of carbon dioxide in mineral-forming fluids during the resolution of certain geological problems (as exemplified by the granite massifs of the Ukrainian Shield), in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 175-179 (in Russian).

MAUGER, R.L., 1988, Ocelli: Transient disequilibrium features in a lower Carboniferous minette near Concord, North Carolina: Canadian Mineral., v.26, p.117-131. Author at Dept. of Geology, East Carolina Univ., Greenville, North Carolina 27858.

The dike contains carbonate-dominant (CDO) and feldspar-dominant (FDO) ocelli. The CDO grew as immiscible carbonate-melt droplets in the dike. Of possible origins for the FDO, only the crystallization of silicate solute droplets condensed from dense fluid-phase bubbles is viable. Rapid decompression, as the magma rapidly rose from mantle or lower crustal depths, generated strong simultaneous oversaturations in fluids (H_2O+F) and carbonates. Dissolved carbonates lowered fluid solubilities, allowing for fluid-phase oversaturations with relatively small fluid contents ($H_2O+F \leq 3$ wt.%) in the magma. High diffusivities for alkalis, H_2O, and F promoted rapid growth of the fluid-phase bubbles while OH^- and F^- solubilities gradually rose, and the fluid-phase H_2O and F redissolved in the magma. Condensed silicate solute from the bubbles remained as compositionally distinct droplets (mostly normative alkali feldspars and minor quartz, devoid of MgO) embedded in the magma. Rapid cooling preserved the droplets as the FDO. (From author's abstract)

MAUS, D.A., 1988, Ore controls at the Golden Rule mine Cochise County, Arizona: MS thesis, The Univ. Arizona.

Mineralized quartz veins in the Golden Rule mine area, Cochise County, Arizona, show increased Au content in areas adjacent to or within the locally glauconitic and pyrite-rich calcareous rocks of the Cambrian Abrigo Formation. Fluid inclusion studies indicate that quartz veins containing base and precious metals formed from an early 275-315°C, CO_2-rich fluid of low salinity (2-7 wt % NaCl) and a later 195-235°C fluid of slightly higher salinity. P estimates obtained from density measurements on P inclusions imply a high P environment, possibly > 1500 bars. The results of the fluid inclusion studies and the implications based on mapping, geophysical information, and sulfur isotope data suggest that the ore bodies may have formed on the periphery of an intrusion. (Author's abstract)

MEDEIROS NETO, F.A., 1986, Chemical and mineralogical zoning in the Pojuca deposit, Serra dos Carajás; a potential mineral exploration tool: Anais XXXIV Congresso Bras. Geol., Goiania, Goiás, v. 4, p. 1541-1555 (in Portuguese; English abstract).

For fluid inclusion data see Medeiros Neto, 1985, Fluid Inclusion Research, v. 18, p. 274-275. (K. Fuzikawa)

MEGAW, P.K.M., 1988, Geochemical characteristics of spatially distinct massive sulfide and skarn mineralization in the Santa Eulalia mining district, Chihuahua, Mexico: Are they equivalent? (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A38. Author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

The Santa Eulalia District shows strong contrasts between massive-sulfide ores (with minor skarn) in its West Camp (WC) and calc-silicate skarn ores (with minor massive-sulfides) in its East Camp (EC). Mineralization in both camps has similar geological relations, and is intimately related to felsite intrusions which have identical whole rock and REE chemistry. Limited age dating suggests they are contemporaneous. Sulfide mineralogy and paragenesis is identical in both camps, and each camp is surrounded by similar, but non-overlapping, alteration halos.

Sulfur isotope values for WC sulfides range from -1 to -18 permil (CDT) (n = 60) with peaks at -10.5 and -15 permil. There is no systematic difference between ore types, nor is there WC-wide isotopic zonations. EC sulfide isotope values range from +4.5 to -13.5 permil (CDT) (n = 19), with peaks at +2 and -12 permil, which correspond to skarn sulfides and massive sulfides respectively. Gross isotopic disequilibrium between coexisting sulfide pairs is typical of both camps.

FI analyses from syn-sulfide fluorite from both camps reveal Th between 200 and 400°C, with corresponding salinities of 3-13 wt% NaCl eq. Neither camp shows vertical T or salinity zoning. WC results reveal a dilution trend, whereas EC values demonstrate a combination of cooling and dilution.

The similarities between WC and EC mineralization suggest that both formed contemporaneously from the same hydrothermal source. If true, the marked mineralogical contrasts must have resulted from: silica source or mobility differences; proximity to the hydrothermal source; degrees of dilution and fluid mixing; or a combination thereof. (Author's abstract)

MEGAW, P.K.M., RUIZ, Joaquin and TITLEY, S.R., 1988, High-temperature, carbonate-hosted Ag-Pb-Zn(Cu) deposits of northern Mexico: Econ. Geol., v. 83, p. 1856-1885. Authors at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

The high-T, carbonate-hosted manto, chimney, and pod Ag-Pb-Zn(Cu) deposits of northern Mexico occur in thick carbonate-dominant Jurassic-Cretaceous basinal sedimentary sequences floored by Paleozoic or older crusts.

Despite the variations between ore types, major similarities are seen in structural controls, host-rock characteristics, and sulfide mineralogy. Geochemical data for the deposits are sparse but indicate strongly contrasting conditions among some of the major districts. Fluid inclusion data indicate T in the range 200° to 500°C and salinities ranging from 1 to 60 eq wt % NaCl. The hotter, more saline, solutions are typically from skarn zones. Evidence for boiling has not been reported. The skarn ores of Naica, Concepcion del Oro, and Valardena show tight clustering of sulfide S isotope values near 0, whereas the skarn and massive sulfide ores of Santa Eulalia show a wide range of values. In most cases there is isotopic disequilibrium between galena and sphalerite, pyrrhotite, or pyrite. Calcite veinlet stockworks above mineralization and limestone wall rocks adjacent to mineralization show shifts of C and O isotopes to lighter values. The tightly clustered S isotopes and high-T, high-salinity fluid inclusions have been interpreted as indicating a strong magmatic component in the mineralizing fluids at Naica, Concepcion del Oro, and Valardena, but Santa Eulalia and other districts show evidence suggesting extensive mixing between magmatic and meteoric fluids.

It appears that the spectrum of mineralization styles shown by these deposits represent differing responses to variations in intrusive associations, depth of emplacement, host-rock characteristics, and geochemical evolution of the individual systems. (From the authors' abstract by E.R.)

MENDELSSOHN, M.J., MILLEDGE, H.J., COOPER, G.I., BOYD, S.R., PILLINGER, C.T., and SEAL, M., 1988, Infrared microspectroscopy of diamond in relation to mantle processes (abst.): EOS, v.69, p.500. First author at Dept. of Geol. Sci., University College London, Gower St., London WC1E 6BT UK.

Diamonds are known to contain significant amounts of important mantle volatiles such as O, N, H and CO_2, and because diamonds can withstand extremes of P and T in non-oxidizing conditions, chemically zoned inhomogeneities survive, thus providing a fossil geochemical record of the volatile composition of the mantle extending over perhaps 3 billion years.

FTIR measurements can now be made on submilligram aliquots, and such data can then be used to constrain models of mantle development. (modified from the authors' abstract)

MENDES, J.C. and SVISERO, D.P., 1988, Solid and fluid inclusions in Santa Teresinha de Goiás emeralds and its geological significance: Anais do XXXV Congresso Brasileiro de Geol., Belém, Pará, Brasil, v. 1, p. 398-405. First author at Dep. de Geol., Univ. Federal de Ouro Preto, Morro do Cruzeiro, CEP 35400, Ouro Preto, Minas Gerais, Brasil.

The following minerals were identified as P inclusions in emeralds from Santa Terezinha de Goiás (State of Goiás); chromite, dolomite, magnesite, talc, phlogopite, pyrite, quartz, beryl, barite, patronite, ferropargasite, anthophyllite-cummingtonite, epidote, melanterite and dumortierite, by X-ray diffraction, X-ray energy dispersive analyses, and electron microprobe. The deposit, located 22 km from the locality of Santa Terezinha de Goiás in central Goiás State, is the main worldwide emerald producer. Emeralds are embedded in talc schists, and biotite/phlogopite schists, as well as in carbonated veins belonging to the Santa Terezinha metasedimentary-metavolcanic sequence.

Chromite is the most common and characteristic inclusion. It occurs as isolated or concentrated, idiomorphic crystals. The color is black but at high magnification most of the crystals display a distinctive red brown color. Carbonates, including dolomite and magnesite, usually are found as rhombohedral crystals. Talc is another common inclusion, occurring as minute dispersed flakes within the host emerald. Other conspicuous inclusions are cubic yellow pyrite, phlogopite (although not as common as in emeralds from the other well-known emerald localities of Itabira and Socotó), idiomorphic beryl, and quartz occurring as irregular masses or filling fractures. Barite and patronite are rare; in addition, epidote, cummingtonite-anthophyllite, dumortierite and melanterite were identified only in mixtures by X-ray methods. Fluid inclusions, observed only at high magnifications, are present as several types of cavities containing gas, liquid and solid phases. The mineral inclusions observed in these emeralds are consistent with the paragenesis of the metamorphic country rocks. Chemical data of the main inclusion phases show in addition an extensive variation in the crystallization conditions of the emeralds. (Authors' abstract)

MENZIES, M.A., 1988, Metamorphic processes; mantle melts in diamonds: Nature, v. 335, p. 769-770.

A discussion of Navon et al. (this volume). (E.R.)

MENZIES, M.A. and HAWKESWORTH, C.J., eds., 1987, Mantle metasomatism: Academic Press Geol. Series, London, 472 pp.

Of particular pertinence to the problems of the nature of the fluids that have caused simple enrichment in certain elements, and those that have metasomatized mantle materials. (E.R.)

MERNAGH, T.P. and WILDE, A.R., 1988, Raman microprobe studies of fluid inclusions from some Australian unconformity-related uranium deposits (abst.): Eleventh Int'l. Conf. on Raman Spectroscopy, Clark, R.J.H. and Long, D.A., eds., 5-9 Sept. 1988, London, England, Publ. John Wiley & Sons, New York, p. 917-918. Authors at Bureau Min. Resources, Canberra, ACT. 2601, Australia.

Fluid inclusions were studied in quartz samples from the unconformity-related deposits of Nabarlek and Koongarra. These inclusions contain gas, liquid, and up to eleven solid phases, to >95 vol.% vapor.

Raman microprobe analyses of the vapor phase revealed three distinct gas compositions. The most common mixture contained mainly CO_2 (usually greater than 80%) and minor amounts of CH_4 and N_2. Approximately 20% of the inclusions contained a binary mixture of CH_4 and N_2 while a few were found to contain a CO_2-N_2 gas mixture. The partial P of methane in the vapor phase was determined for the P dependent frequency shift of the 2917 cm^{-1} Raman band of CH_4. The mean partial P of methane in the inclusions was 7.2×10^6 Pa. CO_2 densities were estimated from the Fermi doublet of CO_2 and ranged from 0.18 to 0.56 gm/cm^3 with a mean of 0.22 gm/cm^3. The vapor P and densities indicate that the inclusions formed at depths between 500 and 2000 m.

Fluid inclusions from Nabarlek commonly contained one or more solid phases while those from Koongarra only occasionally contained solid phases. NaCl is the most common solid in the inclusions; identified in part on the basis of bands corresponding to $NaCl \cdot 2H_2O$ in the low-T Raman spectra. Anhydrite, dolomite (or calcite), and hematite were also identified by Raman spectra.

The salinity of the aqueous phase in the inclusions was determined from a skewing parameter applied to the O-H profile of the Raman spectrum. This allowed the inclusions to be classified into three groups on the basis of salinity; a low salinity fluid (0 - 2 m Cl^-), a high salinity (3 m - 6 m Cl^-), and inclusions containing greater than 75 vol.% vapor and a low salinity fluid. Raman spectra from frozen inclusions confirmed the presence of ice/hydrate crystallites and also showed systematic variations with salinity (see Fig. 1). Estimates of salinity from the frozen inclusions compared favorably with those determined at room T. No variation in the range of total salinity between inclusion fluids from Nabarlek and Koongarra was observed.

The above results are consistent with the presence of two fluids: a basinal brine, comparable in T, P and pH, to modern heavy-metal-bearing oil field brines; and a low salinity Ca^{2+}- and Mg^{2+}-rich groundwater. The oxidized, acidic and high salinity brine is an ideal solution for metal transport. Ore deposition may have been in response to reduction by methane-bearing fluids, or another mechanism such as mixing of fluids of markedly different salinity. (From the authors abstract by E.R.)

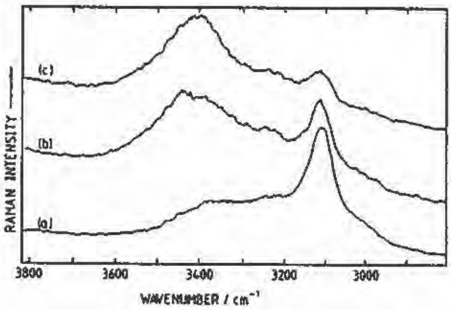


Fig. 1. Raman spectra of ice/hydrate phases in inclusions at 130 K: (a) 0.5 m Cl^-, (b) 3.5 m Cl^-, and (c) 6.2 m Cl^-.

METRICH, Nicole, 1988, Experimental evidence of selective Na enrichment of melt inclusions in quartz: C.R. Acad. Sci. Paris, v. 307, Série II, p. 1887-1892 (in French with abridged English version).

Chemical exchanges between H_2O-rich rhyolitic melt inclusions and host quartz were investigated at 810°C. After 3 to 28 days heating, at 1 atm, in air, microprobe analyses indicate a significant Na enrichment of glass inclusions (Na_2O = 4 to 7.7 wt%). A negative correlation between the Na_2O content of included glasses and the volume of the cavities is demonstrated. After 3 days heating at $P(H_2O)$ = 150 MPa, no chemical or morphologic modification of the cavities was observed. The results suggest that Na migrated from the quartz towards the melt inclusions, considering that the Na content of the host quartz was in the range 13 to 16 ± 1 ppm. (Author's abstract)

METRICH, N. and MOSBAH, M., 1988, Carbon content of basaltic glasses: Nuclear microprobe analysis: Bull. Minéral., v. 111, p. 511-522 (in French; English abstract).

C concentrations have been determined in basaltic glasses using the $^{12}C(d,p)^{13}C$ nuclear reaction technique. The selected energy of the incident charged particles (1.4 MeV) allows an accurate determination of the deep C. In oceanic tholeiitic glasses (glassy rims of pillow-lava) from E.P.R. (20°49') C ranges in concentration from 30 ppm (close to the detection limit) to 130 ppm $P(CO_2)$ = 25-30 MPa) after the nucleation of the CO_2 vesicles. The dissolved C contents of the alkali basalt glasses, trapped in the olivine phenocrysts ($Fo_{81.7}$) from Etna volcano, vary from 450 to 700 ppm. But carbonates (dms) occur on the walls of the shrinkage bubbles of the melt inclusions as the result of post-entrapment reactions between a CO_2 fluid phase and the glass. C is much lower (60 ppm) in the melt inclusion of olivine (Fo_{82-86}) from Piton de la Fournaise volcano (Reunion Island). Our results exhibit: 1) a heterogeneous distribution of C in the submarine glasses, probably related with the CO_2 vesicles nucleation process; and 2) a relation between the C content of the melt inclusions and the P ($P(CO_2)$) of crystallization of the host mineral. (Authors' abstract)

METRICH, N., MOSBAH, M., TIRIRA, J. and TROCELLIER, P., 1988, Nuclear microprobe analysis. Application to the volcanic glasses (abst.): Chem. Geol., v. 70, p. 177. Authors at Groupe des Sci. de la Terre LPS-CNRS-CEA CEN Saclay 91191 Gif sur Yvette, France.

Nuclear microprobe has been used to determine the dissolved carbon content of submarine glasses (E.P.R.) and of melt inclusions trapped in the phenocrysts of lavas from different volcanoes (Etna, Sicily; Piton de la Fournaise, Réunion Island). Using $^{12}C(d,p)\,^{13}C$ reaction, the detection limit in basaltic glasses is 30-40 ppm, with 1.4 MeV as incident deuteron energy and a beam diameter around 5 to 10 μm. The possibility and the limit of the method will be discussed for other light elements such as H and F, these elements being analyzed, respectively, by elastic recoil and resonant nuclear reactions. (Authors' abstract)

METRICH, N., MOSBAH, M., TROCELLIER, P. and CLOCCHIATTI, R., 1986, Nuclear microprobe analysis of carbon within glass inclusions and volcanic materials, in 11th Int'l. Cong. on X-ray Optics and Microanalysis, London, Canada, 4-8 Aug., 1986, eds. J.D. Brown and R.H. Packwood, Proccedings, 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)

MEUNIER, J.D. and BREIT, G.N., 1988, Paleofluids in the copper and uranium-bearing sandstones, central Colorado Plateau: Fluid inclusion and isotopic evidence in calcite (abst.): Chem. Geol., v. 70, p. 186. Authors at CREGU & GS CNRS-CREGU, BP 23, 54501 Vandoeuvre lès Nancy cedex, France.

The T and composition of fluids which altered sandstones hosting copper and uranium deposits on the Colorado Plateau, USA, were assessed using fluid inclusions and stable isotopes ($\delta^{13}C$ and $\delta^{18}O$). The copper deposits are fault-controlled red bed-type that occur mainly in coal-bearing Cretaceous sandstones. The uranium deposits are epigenetic, tabular layers associated with detrital plant fragments in Jurassic sandstones.

$\delta^{13}C$ values, ranging from -2 to -9 per mil (PDB) may reflect addition of carbon from the different wall-rocks. Calcites in faults near copper deposits in Lisbon Valley, Utah, and calcite replacing wood in sandstones hosting uranium deposits within the adjacent Slick Rock district, Colorado, have similar fluid inclusions and oxygen isotopic compositions. Th range from 70 to 100°C and Tm range from 0 to -10°C corresponding to salinities of 0 to 14 wt. % eq. NaCl. $\delta^{18}O$ in calcite ranges from 16 to 18 per mil (SMOW). These results indicate that similar fluids moved in both localities. These fluids are related to copper mineralization. In the Lisbon Valley, high T (Th = 90-95°C) and saline solution postdated a low T (Th <80°C) and dilute solution. Then, fluids of different composition passed through the fracture system at different time. Aqueous solutions which precipitate the calcite are characterized by $\delta^{18}O$ of -4 to -1 per mil (SMOW). These values are consistent with basinal brines. Flow of these solutions outward from the faults recrystallized carbonate cements in adjacent sandstones and may have influenced constituent[s] of the U-V deposits. Calcite in the Dolores zone of faults from the Morrison Formation in the Slick Rock district, have $\delta^{18}O$ of 7 to 11 per mil (SMOW), the included fluids are dilute with Th = 50°C. Then, calcite from the Dolores zone of faults have a distinct origin and formed from a water with a $\delta^{18}O$ of -15 per mil (SMOW) which is identical to the isotopic composition of modern and middle Tertiary meteoric water in the area. (Authors' abstract)

MEYER, A.J., BROSSE, E., LANDAIS, P. and PAGEL, M., 1988, Thermal history of the breccia pipes area (Arizona) by fission track analysis (abst.): Terra cognita, v. 8, p. 19-20. Authors at Centre de Recherches sur la Géol. de l'Uranium and GS CNRS-CREGU, BP 23, Vandoeuvre-les-Nancy, France.

The thermal history of the breccia pipes area (Grand Canyon region, Arizona) has been evaluated using apatite fission track analysis (length reduction) and compared with fluid inclusion and organic matter data. Samples of Permian reservoir facies (Coconino sandstone) and oil source-rocks (Toroweap limestone) have been studied.

An age of 55 ± 5 Ma (2δ) is obtained using isochron dating technique on detrital apatites from the Coconino sandstones, but track length analysis shows that the spontaneous tracks are shorter than the induced tracks. Thus, this is an apparent age which must be corrected.

The bimodal distribution of projected lengths of spontaneous tracks gives evidence about thermal event posterior to the of the Permian sedimentation. Mathematical treatment of the histogram was carried out in order to calculate the Ps/Pi ratio and to determine the corrected age for each population.

The total corrected age is 300 ± 40 Ma (2σ). The end of the thermal event responsible for the observed track fading is dated at 65 ± 5 Ma (2σ). This is related to the Cretaceous uplift in this area. The associated T integrated over 50 million years averages 135°C. Fluid inclusion results as well as data extracted from organic geochemistry analyses and geological reconstruction indicate maximum T ranging 100°C and 140°C. Such hypothesis was tested using MATOIL and KINES programs (I.F.P.) and appeared to be in good agreement with computerized modelling of Rock Eval Tmax of Toroweap organic matter. (Authors' abstract)

MEYER, H.O.A. and MITCHELL, R.H., 1988, Sapphire-bearing ultramafic lamprophyre from Yogo, Montana: A ouachitite: Canadian Mineral., v.26, p.81-88. First author at Dept. of Earth & Atmosph. Sci., Purdue Univ., West Lafayette, Indiana 47907.

Of pertinence only because sapphires from this locality contain large (and, in part, inexplicable) inclusions of CO_2 and unknown phases. (E.R.)

MICHAEL, P.J., 1988, The concentration, behavior and storage of H_2O in the suboceanic upper mantle: Implications for mantle metasomatism: Geochim. Cosmo. Acta., v.52, p.555-566. Author at Dept. of Geol. Sci., Univ. of British Columbia, Vancouver, B.C., Canada, V6T 2B4

Mid-ocean ridge basalt glasses from the Pacific-Nazca Ridge and the northern Juan de Fuca Ridge were analyzed for H_2O by gas chromatography. Incompatible element enriched (IEE) glasses have higher H_2O contents than depleted (IED) glasses. H_2O increases systematically with decreasing Mg/Mg + Fe^2 within each group. Near-primary IED MORBs have an average of about 800 ppm H_2O while near-primary IEE MORBs (with chondrite normalized Nb/Zr or La/Sm $\approx$ 2) have about 2100 ppm H_2O. If these basalts formed by 10-20% partial melting then the IED mantle source had 100-180 ppm H_2O, while the IEE source had 250-450 ppm H_2O. The ratio $H_2O/(Ce + Nd)$ is fairly constant at 95 ± 30 for all oceanic basalts from the Pacific. During trace element fractionation in the suboceanic upper mantle, H_2O behaves more compatibly than K, Rb, Nb, and Cl, but less compatibly than Sm, Zr and Ti.

H_2O is contained mostly in amphibole in the shallow upper mantle. At P greater than the amphibole stability limit, it is likely that a significant proportion of H_2O is contained in a mantle phase which is more refractory than phlogopite at these P.

The role of H_2O in mantle enrichment processes is examined by assuming that an enriched component was added. The modelled concentrations of K, Na, Ti and incompatible trace elements in this component are high relative to H_2O, indicating that suboceanic mantle enrichment is caused by silicate melts such as basalt and not by aqueous fluids. (Author's abstract)

MICHARD, A., 1988, Rare earth abundances in geothermal waters (abst.): Chem. Geol., v. 70, p. 163. Author at CRPG-ENSG, Vandoeuvre, France.

Waters with different venting and bottom T, variable pH and dominant anions were analyzed for their REE contents.

CO_2-rich solutions nondiluted by sub-surface water from Massif Central (France) show a contrasting behavior between cold (13-18°C) waters, which show a pronounced HREE enrichment (Ce = 0.010 ppb, Dy = 0.150 ppb), and warm waters (60°C) with a shale-like distribution. These patterns suggest a transfer of the LREE from the solution to the country rock and a reverse direction of transfer for the HREE when the solutions cool down within the sedimentary reservoir. The mineral phases involved in the exchange process are still unidentified but the presence of abundant bicarbonate is apparently of prime importance.

Acid-suilfate waters from Valles Caldera, New Mexico, and Dominica Island have pH <4 and moderate venting T (45-90°C). They have the highest REE content ever found in fluids (up to 0.2 ppm of Ce). Their patterns present a systematic LREE enrichment with a variable negative Eu anomaly which are interpreted as reflecting the distribution of the REE extracted from the diverse and deeply altered rocks along the conduits.

Cl-rich waters with T >250°C, and pH <6 from variable geological environments (basalts from the East Pacific Rise at 13 and 21°N, rhyolites and sandstones from Salton Sea, California, tuffs and latitic lavas from Mofete, Phlegraean Fields) have similar profiles with LREE enrichment and a huge Eu positive anomaly. The Eu/Eu* ratio much higher in the fluids than in the rocks suggests that a large proportion of Eu in these fluids is in the divalent state.

In high-pH solutions (>7) solutions of variable T (45-240°C), the REE content is very low: the most abundant REE is Ce with a concentration of less than 0.07 ppb. Continued next page.

In general, the REE contents of hydrothermal solutions are dominantly controlled by pH more than by T. All the cases studied suggest that hydrothermal activity at T <350°C is not expected to affect significantly the REE balance of rocks unless very high water/rock ratios are achieved (>100). Experimental determination of the REE partitioning between minerals and solutions under different conditions of T, pH, anion content... are needed for a quantitative understanding of the REE controls in solutions. (Author's abstract)

MICHARD, Gil, 1987, Controls of the chemical composition of geothermal waters in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 323-353. Author at Lab. Géochimie des Eaux, Univ. Paris 7, 75251 Paris Cedex 05, France.

Studies of numerous hot water geothermal systems have demonstrated that geothermal waters approach equilibrium with either P minerals of rocks or with S minerals resulting from water-rock interaction. Simple calculations of the composition of water at equilibrium can be performed by using the concept of complete mineral association: the number of minerals is equal to the number of major inert elements in the solution. For each element, the ratio Me_H (= $a(Me^{Z+})/[a(H^+)]^Z$) is fixed. In the T range 0-300°C, in the P range 0-1 kbar and for mineral commonly encountered in geothermal systems, Me_H depends strongly on T, is almost independent of P, and depends only slightly on the nature of the minerals. Concentrations of inert elements are highly affected by the amount of mobile elements present in the solution. When this amount is high, variations in inert ions concentrations are directly related to the electric charge of the ion: elevated concentrations of Cl, for instance, increase tri- or divalent cation concentrations more than monovalent cation concentrations and decrease anion concentrations. Trace element behavior is dominated by partition processes: dissymetry between dissolution (without trace-major fractionation) and precipitation (with fractionation) can be used to evaluate the extent of dissolution of P minerals and precipitation of S minerals. (Author's abstract)

MICHELS, D.E., 1988, Salinity stabilization for non-advecting brine in a temperature gradient with applications to the Salton Sea geothermal system: Geother. Resources Council, Transactions, v. 12, p. 127-130.

MILLERO, F.J., 1988, Effect of ionic interactions on the rates of oxidation of metals in natural waters (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated).

MIN, M., KONG, L., ZHANG, Z., JIANG, Y. and ZHANG, G., 1987, Geological features of a uranium deposit and its hydrothermal superimposition and transformation ore-forming processes: Mineral Deposits [Beijing, China], v. 6, no. 4, p. 72-80 (in Chinese; English abstract).

Mineralization T range [from fluid inclusions?] was 100-300°C, with the deposition of the pitchblende occurring at 150-300°C. Meteoric fluids dominated the system. The origin of the U was mainly from the surrounding L granites. (E.R.)

MIRONOVA, O.F. and ROSTOTSKAYA, N.M., 1988, The possibilities of the pyrochromatographic method in analyzing fluid inclusions in minerals, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 90-95 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 278-279. (E.R.)

MIRONOVA, O.F., SAVEL'EVA, N.I., IKORSKY, S.V. and VASYUTA, Yu.V., 1988, A comparison of the results of a bulk analysis of the fluid inclusions using different methods of extracting the gas phase, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 64-68 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 279. (E.R.)

MISRA, K.C. and GRATZ, J.F., 1988, Evolution of mineralizing fluids, Gordonsville zinc deposit, central Tennessee, U.S.A.: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 225-236. Authors at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996-1410, USA.

Fluid inclusion microthermometry and limited data on oxygen and carbon isotope ratios of calcites suggest that the mineralizing fluids for the breccia-fill, Mississippi Valley-type Gordonsville Zn deposit evolved from a highly saline brine during an earlier stage of mineralization to a less saline brine during a later stage of mineralization, probably due to dilution by influx of ^{13}C-depleted meteoric water. There is no evidence from fluid inclusion data that sphalerite precipitation was caused by fluid mixing. (Authors' abstract)

See also Gratz and Misra, 1986, Fluid Inclusion Research, v. 19, p. 161, and 1987, Fluid Inclusion Research, v. 20, p. 143-144. (E.R.)

MITROPHANOV, F.P., YAKOVLEV, Yu.N., IKORSKY, S.V., YAKOVLEVA, A.K., VETRIN, V.P., NERADOVSKY, Ya.N., TOLSTIKHIN, I.N., LANEV. V.S., SMIRNOV, Yu.P. and RUSANOV, M.S., 1988, Change in composition of mineral phases and gas microinclusions with depth in the section of the Archean complex in super-deep borehole (SD-3) (abst.): Min. Geol. of USSR Inter-Union Comm. on the Lithosphere Int'l. Seminar, "Super-deep continental drilling and deep geophysical research" abstracts, Aug. 23-29, 1988, p. 236-238.

The rocks of the Archean complex were intersected by the super-deep borehole-3 in the interval of 6.84 to 12.06 km. The rocks consist of metamorphic succession characteristic of the Kola-White Sea series. (...)

The relationship between major components in microinclusions of gases has been found to change with depth. If the near-surface part of the section the methane/helium ratio averages 25, however, the content of helium already exceeds that of methane 1.8-3.9 times at a depth interval of 7-11 km and 23 times at depth of 11-12 km. The $^3He/^3He$ [sic; probably $^3He/^4He$] ratio is found to be (2-14) $\cdot$ 10^{-8}, which proves a minor, but reliably established mantle source. Within the Archean complex the $^3He/^4He$ ratio gradually decreases with depth. The isotopic composition of other noble gases points to their radiogenic origin. This might suggest that during regional metamorphism of the Archean sequences had chiefly been influenced by crustal fluids.

The variations in composition of ore minerals and microinclusions of gases disclosed in Archean rocks can be accounted for the thermodynamic conditions existing the deep portions of borehole 3. Hence new aspects of the phenomenon can be encountered during further drilling. (From the authors' abstract by E.R.)

MOECHER, D.P. and ESSENE, E.J., 1988, Scapolite phase equilibria: Further constraints on fluids in granulites (abst.): Terra cognita, v. 8, p. 255. Authors at Dept. Geol. Sci., Univ. Michigan, USA.

Low water activities (aH_2O) and carbonic fluid inclusions have been taken as evidence that CO_2 is the major component of the fluid phase in granulite facies lithologies. However, the fluid inclusion data are equivocal and direct calculation of peak fluid compositions is necessary. Recently acquired thermodynamic data and a-X relations for carbonate scapolite were used to calculate CO_2 activities (aCO_2) in several granulite terranes. The assemblage Scap-Pg-Gt-Qz, common in scapolite-bearing granulites, allows calculation of aCO_2 by the reaction Meionite + Qz = An + Gr + CO_2 using Gt-Opx-Cpx-Pg-Qz barometry and Gt-Cpx thermometry. Calculated aCO_2 for selected granulites are as follows: Grenville Province of Ontario, 0.4 ± 0.3 (n = 11); Bergen Arcs, Norway, 0.4 ± 0.3 (n = 4); Southern India, 0.2 ± 0.1 (n = 4) for mafic granulites and 0.6 ± 0.0 (n = 2) for calc-silicates. Lower crustal xenoliths from New South Wales, Germany, and Tanzania yield aCO_2 = 0.7 ± 0.1. Thus, calculations do not support a model of a uniformly CO_2-rich fluid phase for these granulites.

Scapolite is pervasively developed in the Furua Complex of Tanzania (Coolen 1980), where calculated aCO_2 from felsic to mafic granulites (n = 15), amphibolite (n = 1), and calc-silicates (n = 2) are 0.2 ± 0.1; in addition aH_2O of 0.2 ± 0.1 (n = 4) was also calculated using Phl + Qz = En + Kfs + H_2O. Fluid inclusions in a mafic granulite are nearly pure CO_2 and are interpreted to be peak metamorphic and related to carbonic metamorphism (Coolen, 1982). However, the fluid calculations indicate either fluid-absent metamorphism or a mixed H_2O-CO_2 fluid.

If H_2O and CO_2 are the dominant fluid species in scapolite granulites, metamorphism in the absence of a fluid phase is indicated. Further evaluation of volatile equilibria is critical in understanding the role of fluids in granulites. (Authors' abstract)

MOISEENKO, V.G. and SOROKIN, A.P., 1988, Mineral-forming fluids, magmatism, and ore formation in the transition zone from the Pacific Ocean to the continent, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 10-20 (in Russian).

MOLINDA, G.M., 1988a Gas outbursts studied at domal salt mines: Geotimes, v. 33, no. 1, p. 12-14.

A discussion of the effects of high-pressure methane inclusions in domal salt from Louisiana. (E.R.)

MOLINDA, G.M., 1988b Investigation of methane occurrence and outbursts in the Cote Blanche domal salt mine, Louisiana: Bureau of Mines Report of Investigations 9186, 21 pp. Author at Pittsburgh Res. Center, Bureau of Mines, Pittsburgh, PA.

The author correlates the abundance of methane-bearing fluid inclusions and salt crystal size with the tendency of the salt to produce outbursts. (H.E.B.)

MØLLER, Nancy, 1988, The prediction of mineral solubilities in natural waters: A chemical equilibrium model for the Na-Ca-Cl-SO_4-H_2O system, to high temperature and concentration: Geochimica Cosmo. Acta, v. 52, p. 821-837.

MONTANA, Art, WHITE, Brad and BREARLEY, Mark, 1988, Argon, water, and carbon dioxide in silicate liquids to high pressures (abst.): EOS, v. 69, p. 1465. First author at Dept. Earth & Space Sci. & Inst. Geophys. & Planet. Physics, UCLA, Los Angeles, CA 90024-1567.

The study of H-O and C-O components in silicate liquids is complicated because they form molecular (e.g., CO_2) as well as ionic (e.g., CO_3^{2-}) species. To shed light on the solubility mechanisms of these volatile components in silicate liquids, we experimentally compared the melting behaviors of albite and sanidine in the presence of argon, H_2O and CO_2, and we measured viscosities (η) in the presence of H_2O and CO_2. We buffered all experiments with H-M to provide low values of fH_2. Although argon is quite soluble in $NaAlSi_3O_8$ and $KAlSi_3O_8$ liquids (1.1 and 1.3 wt% at 35 kbar, respectively), it depresses the liquidus of sanidine only ~10, 30, and 20°C at 5, 12, and 20 kbar, in contrast to the ~30, 140, and 170° produced by CO_2 and the >300° at P above 5 kbar resulting from H_2O. This decrease with argon agrees with the calculated value using the solubilities of argon of White et al. (1988) and the colligative properties of a simple solute dilution, supporting the assumption that argon dissolves inertly as an atomic species. However, the proclivities of H_2O and CO_2 to form OH and CO_3^{2-} result in enhanced solubility (at least in the case of H_2O) in and depolymerization of $KAlSi_3O_8$ liquid, as evidenced by our phase equilibria and the marked decrease in viscosity (White and Montana, 1988).

In constrast, argon and CO_2 yield similar, small depressions of the liquidus of albite, and CO_2 is not nearly as effective in lowering η as it is in $KAlSi_3O_8$, indicating that molecular species do not interact as energetically with the liquid. The greater effectiveness of CO_2 relative to the molecular species, argon, in stabilizing $KAlSi_3O_8$ liquid to lower T suggests that a higher proportion of carbon dissolves as CO_3^{2-} in $KAlSi_3O_8$ than in $NaAlSi_3O_8$. Furthermore, molecular CO_2 predominates in $NaAlSi_3O_8$, consonant with our finding that argon and CO_2 have similar solubilities in $NaAlSi_3O_8$. This suggests that molecular species do not significantly interact energetically with silicate liquids, as witnessed by the small depressions of the liquidi of albite by CO_2 and argon. (Authors' abstract)

MOORE, J.N. and ADAMS, M.C., 1988, Evolution of the thermal cap in two wells from the Salton Sea geothermal system, California: Geothermics, v. 17, no. 5/6, p. 695-710. Authors at Univ. Utah Res. Ins., 391 Chipeta Way, Suite C, Salt Lake City, UT 84108-1295, USA.

The Salton Sea geothermal system is located near the center of the sediment-filled Salton Trough where T locally reach 365°C at depths of 2 km. The geothermal reservoir is overlain by a thermal cap of low-permeability rocks that restricts the upward movement of the high-T brines. Petrographic and fluid inclusion studies in two wells drilled in the southern part of the field indicate that the thermal cap consists of an upper layer of lacustrine and evaporite deposits with low initial permeabilities and a lower layer of deltaic sandstones. The sandstones were incorporated into the thermal cap as downward percolating fluids deposited anhydrite and calcite in the pore space of the rocks, reducing their permeabilities. During development of the thermal cap, base-metal sulfides, potassium feldspar and quartz were deposited by brines from higher-T portions of the system. (Authors' abstract)

MORETTO, Robert, 1988, Observations on the incorporation of trace elements in halite of Oligocene salt beds, Bourg-en-Bresse Basin, France: Geochimica Cosmo. Acta, v. 52, p. 2809-2814. Author at Univ. Nancy I, Lab. Géol. des Ensembles Sédimen., B.P. 239, 54506 Vandoeuvre-lès-Nancy, France.

It is common practice to employ trace elements found in chloride salts as indicators of the conditions of deposition. Because some halite contains abundant fluid inclusions, it is necessary to separate the salt from the inclusions before analysis. This study presents the data derived from the use of a simple preparative technique which permits analysis of the trace elements in solid halite, and provides a guide to test the success in elimination of the contaminants contained in the fluid inclusions.

The differentiation is accomplished simply by crushing the salt in alcohol followed by separate analysis of the fluid and solid components, thus yielding accurate trace element concentrations in the solids (crystal lattice, dislocations, and grain boundaries) and the fluids. Br and K are present both in the solid and liquid phases of the halite, but Mg is exclusively in the fluid inclusions. The elimination of the Mg from the analysis of the solid phase may thus be employed as a monitor to indicate the degree of purification of the samples being analyzed. (Author's abstract)

MORITZ, R.P., 1988, Geological and geochemical studies of the gold-bearing quartz-fuchsite vein at the Dome mine, Timmins area: PhD dissertation, McMaster Univ., Hamilton, Ont., 280 pp.

The quartz-fuchsite vein at the Dome mine, Timmins area, has been the subject of an integrated field, petrographic, geochemical, and fluid inclusion study to characterize the site and the cause of ore deposition, and to establish the source of ore components in Archean lode Au deposits.

The vein lies in a zone of carbonatized komatiites at the contact with a slate unit. The wall rock alteration that accompanied ore is centered around a porphyry lens located in the zone of carbonatized rocks. The quartz-fuchsite vein is coincident with the outer rim of the alteration envelop.

A high pore fluid regime [pressure?] that developed in the carbonatized komatiites in proximity to the slates resulted in hydraulic fracturing and genesis of the vein. Massive and barren quartz was deposited during protracted stages of fracture growth, while banded and Au-bearing quartz was formed during repetitive and brief periods of crack-seal vein growth. Quartz veining took place before the compressional deformation which has affected the Timmins area.

Fluid inclusion 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 toward higher pH and fO_2. As a consequence, Au complexes were probably destablized in the hydrothermal fluid and deposited with quartz in crack-seal veins.

Pb isotope studies of whole rocks and galenas associated with Au in the vein suggest a genetic link between the Au mineralization and the quartz-feldspar porphyries of the Dome mine environment, although other source reservoirs cannot be ruled out on the basis of Pb isotopes alone. S isotope compositions of pyrites and galenas from the vein are compatible with a magmatic or a metamorphic fluid.

The weight of evidence indicates that the development of the Au mineralization in the quartz-fuchsite vein is genetically related to the emplacement of quartz-feldspar porphyries in the Dome mine environment. The ultimate source of Au and the mineralizing fluid is probably a deeper seated magma, or possibly the lower crust. (Author's abstract)

MOROZOV, S.A. and GRIGOR'EVA, E.P., 1988, Features of the origin of the gold-ore mineral associations of Tadzhikistan, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 140-146 (in Russian).

MORRISON, G.W., 1988, Paleozoic gold deposits of northeast Queensland (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 91-101. Author at Geol. Dept., James Cook Univ., Townsville Qld 4811.

Quotes literature data on fluid inclusions to show that a series of

Au deposits all show early potassic alteration with Cu-Mo stockwork mineralization from fluids at ~500°C and 30-50% salinity; the main mineralization stage formed from a magmatic gas condensate at ~300-400°C, <10% salinity, and minor CO_2. (E.R.)

MORRISON, G.W., ANDREW, Anita and TEALE, Graham, 1988, Origin of gold mineralization in the Mount Leyshon diatreme (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 116-120. First author at Geol. Dept., JCUNQ, Townsville, Qld. 4811.

Fluid inclusions suggest that separation of a vapor phase from a high salinity fluid at >500°C was responsible for Stage I mineralization, sericite-pyrite alteration and development of the main diatreme. Stage II and III fluids responsible for the bulk of Au mineralization were of low-moderate salinity, without appreciable CO_2 and at 300-400°C. They may have developed from condensation of Stage I vapor or mixing of a cooler dilute fluid. (From the authors' abstract)

MORRISON, J. and VALLEY, J.W., 1988a, Post-metamorphic fluid infiltration into granulites from the Adirondack Mts., USA: J. Geol. Soc. India, v. 31, no. 1, p. 91-93. Also in Lunar Plan. Inst. Tech. Rept. 88-06, p. 115-117. Authors at Univ. Wisconsin, Madison, WI.

We interpret the textures to indicate that many apparently pristine samples have been infiltrated by retrograde CO_2-H_2O fluids. We have analyzed the carbon and oxygen isotope composition of calcite and oxygen in plagioclase. We interpret the data to indicate that the oxygen isotope composition of the calcite was controlled primarily by the hydrothermal fluids. Mixed H_2O-CO_2 fluid inclusions provide minimum T for the alteration of ≈ 350°C. The calcite values are intermediate between those of igneous rocks and marbles, which suggests that the hydrothermal fluids exchanged with both meta-igneous and supracrustal lithologies. (From the authors' abstract by E.R.)

See also next item. (E.R.)

MORRISON, Jean and VALLEY, J.W., 1988b, Post-granulite facies fluid infiltration in the Adirondack Mountains: Geology, v. 16, p. 513-516. First author at Dept. Geol. Sci., Univ. Southern California, Los Angeles, CA 90089.

Granulite facies lithologies from the Adirondack Mountains of New York, contain alteration assemblages composed dominantly of calcite ± chlorite ± sericite. These assemblages document fluid infiltration at middle to upper crustal levels. Cathodoluminescence of samples from the Marcy anorthosite massif indicates that the late fluid infiltration is more widespread than initially indicated by transmitted-light petrography alone. Samples that appear unaltered in transmitted light show extensive anastomosing veins of calcite (<0.05 mm wide) along grain boundaries, in crosscutting fractures, and along mineral cleavages. The presence of the retrograde calcite documents paleopermeability in crystalline rocks and is related to the formation of high-density CO_2-rich fluid inclusions. Recognition of this process has important implications for studies of granulite genesis and the geophysical properties of the crust. (Authors' abstract)

MORRISON, S.J. and PARRY, W.T., 1988, Age and formation conditions of alteration associated with a collapse structure, Temple Mountain uranium district, Utah: Geol. Soc. Am. Bull., v. 100, p. 1069-1077. First author at UNC Geotech., P.O. Box 14000, Grand Junction, CO 81502-5504.

Temple Mountain, Utah, is an erosional remnant capped by resistant dolomitic alteration of the Triassic Wingate and Chinle Formations. Carbonate, Fe-oxide, phyllosilicate, sulfate, and other mineral alterations are related to a collapse structure. Elemental zoning (Cr, Cu, Co, Ni, As) of the ore district is unlike that found in other U districts hosted by the Chinle Formation. A major U ore belt in the Chinle Formation partially encircles the collapse structure ~500 m away. Two theories on the genesis of the Temple Mountain district have been proposed. Both suggest a relationship between alteration, ore mineralization, and formation of the collapse structures but differ substantially as to the intrinsic parameters of the alteration/ore-mineralizing fluids. One theory suggests hydrothermal solutions up to 350°C, whereas the other proposes cool solutions rich in CO_2. Fluid inclusion data collected from alteration dolomite and sphalerite and geochemical modeling of a CO_2-rich system support aspects of the latter theory. Median Th for fluid inclusions in dolomite, calcite, quartz, and sphalerite are 67, 59, 74, and 73°C, respectively. Fluid salinity measured in inclusions in sphalerite is 7.8 to 9.7 eq. wt % NaCl. Alunite, spatially associated with U mineralization and the collapse structure alteration, has been dated at ~13 Ma by K-Ar methods. Acid solutions containing carbon and sulfur derived from natural gas dissolved carbonate, caused collapse, and transported and fixed U as oxidation states varied. (Authors' abstract)

MOUNTAIN, B.W. and WOOD, S.A., 1988, Chemical controls on the solubility, transport, and deposition of platinum and palladium in hydrothermal solutions: A thermodynamic approach: Econ. Geol., v. 83, p. 492-510. Authors at Dept. Geol. Sci., McGill Univ., 3450 University St., Montreal, Quebec, Canada H3A 2A7.

Studies indicate that up to 300°C, complexation by either OH^-, HS^-, or Cl^- can contribute to the transport of these metals in hydrothermal solutions. These calculations suggest that Pt and Pd may be mobile in a variety of environments. In kupferschiefer-type ore-forming fluids they could be transported as chloride complexes. The lack of acidic alteration and oxidized mineral assemblages in hydrothermal Pt and Pd occurrences in shear zones in metagabbroic rocks preclude Pt and Pd transport as chloride complexes during formation of these deposits. In these cases, bisulfide and/or hydroxide complexes are more likely responsible for precious metal transport. (From the authors' abstract by E.R.)

MUEHLENBACHS, Karlis and NESBITT, B.E., 1988, Generation of mesothermal Au deposits by deep convection of meteoric water (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 62. Authors at Dept. Geol., Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

Mesothermal lode Au deposits in metamorphic terranes (Mother Lode, Calif.; Archean deposits) have previously been regarded to be a product of metamorphic devolatilization. However, recent geochemical data from such deposits in the Canadian Cordillera indicate that they formed from deeply (12-15 km) convecting meteoric waters. $\delta^{18}O$ values for quartz from these deposits range from +12 to +18‰ with calculated $\delta^{18}O$ values for the ore fluids of +5 to +11‰. Such values are generally regarded as indicating a magmatic or metamorphic origin for the fluids. However, δD values from fluid inclusions and silicates are quite negative (-100 to -160‰) and latitudinally dependent indicating that the principal fluid component was highly evolved meteoric water. $\delta^{13}C$, $\delta^{34}S$, Rb/Sr and Nd/Sm data imply the derivation of the ore-forming components from sedimentary units adjoining and underlying the units hosting the ores. Fluid inclusion studies indicate T of deposition of 250 to 350°C and P of 1 ± 0.2 kbars, which corresponds to a depth estimate of 8 to 12 km assuming a hydrostatic P gradient. Stable isotope studies of Hg and Sb deposits in Canadian Cordillera demonstrate that these deposits formed from fluids similar in chemistry to the Au-forming fluids, but at lower T and P. Calculations involving Rayleigh/Darcy equation show that permeabilities in the brittle regime are sufficiently high to permit free convection of meteoric water to the brittle/ductile transition at depths of 12-15 km. Close spatial relationships between the Hg, Sb and Au deposits and major transcurrent faults suggest that the principle zones of permeability are provided by deformation associated with these faults. (Authors' abstract)

MÜLLENMEISTER, H.J., 1988, New discoveries in Dominican amber: Z. Dt. Gemmol. Ges., v. 37, p. 1-25 (in German; English abstract).

This paper discusses curious palaeontological discoveries of organisms whose situation in life is permanently sealed in Dominican amber. Multiple phase inclusions - among them an inorganic one - are demonstrated by photomicrographs. (Author's abstract)

MULLIS, J., 1988a, Petroleum- and natural gas-bearing quartz crystals from the northern limestone Alps of Switzerland: Mineralienfreund, v. 26, p. 61-67 (in German).

In this paper the present knowledge about petroleum and natural gas-bearing quartz crystals are compiled. Above all it contains data about the morphology of the crystals, their solid and fluid inclusions, their formation as well as about the topographical mineralogy of these quartz occurrences. (Abstract by H.A. Stalder)

MULLIS, Josef, 1988b, Rapid subsidence and upthrusting in the Northern Apennines, deduced by fluid inclusion studies in quartz crystals from Porretta Terme: Schweiz. Mineral. Petrogr. Mitt., v. 68, p. 157-170. Author at Mineral.-Petrogr. Inst. der Univ. Basel, Bernoullistr. 30, 4056 Basel, Switzerland.

Early fluid inclusions in fissure quartz from Porretta Terme in the Northern Apennines contain methane-bearing water-rich and methane-rich fluids trapped at ~220 to 230°C and 2.0 to 2.1 kbar. These values refer to minimum to approximate rock burial of 8 to 9 km at low grade anchimetamorphic conditions during the Apenninic orogeny.

Sedimentation, subsidence to a depth of at least 8 to 9 km, maximum heating, and upthrusting were short, lasting ~10 Ma. Such a scenario can be explained by rapid subduction-like subsidence beneath the northeast advancing Liguride nappes and rapid upthrusting as a consequence of compressional tectonics.

High fluid P approximated probably lithostatic conditions favoring nappe transport during compressional tectonics. Repeated fluid P drops during crystal growth of 0.5 to 1.5 kbar led to methane-water unmixing and rapid precipitation of skeletal quartz from a methane-rich emulsion-like fluid.

Fluid inclusion data do not correspond with preliminary results of illite 'crystallinity' as they only indicate diagenetic conditions. If fluid T is equal to rock T, fluids probably display, in presence of short-lived heating, greater sensitivity to metamorphism than minerals. (Author's abstract)

MULLIS, J., 1988 - See Matter et al., 1988, this volume. (E.R.)

MULLIS, J. and MEYER, J., 1988 - See Matter et al., 1988, this volume. (E.R.)

MUSGRAVE, John and NORMAN, D.I., 1988, Analysis of fluid inclusion gases from Continental Scientific Drilling Program corehole VC-2a, Valles caldera, N. Mex. (abst.): EOS, v. 69, p. 1508. First author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Corehole VC-2a was drilled as part of the Continental Scientific Drilling Program in the acid-sulfate hot springs system at Sulphur Springs, Valles caldera, NM. Fluid inclusions from 40 to 550 m in VC-2a have Th of 190-220°C, and these were analyzed by mass spectrometry. Gaseous species measured were CO_2, H_2S, CH_4, Ar, N_2, H_2, He, and numerous organic species up to and including C_6. The mole % gaseous species in the analyzed inclusions 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, the latter would be expected to have a high ratio of gases. The low H_2S fluid has gaseous species in similar ratio to the deep geothermal water in the Valles hydrothermal system. Fluids with CO_2/H_2S near 1 have been reported in inclusions from precious metal deposits including those in the Jemez Mountains, and molybdenite, chalcopyrite and sphalerite occur in fractures in the core from VC-2a.

Seismic data suggest that a partially molten intrusive may underlie the Jemez Mountains, and the sulfur-rich fluids may have been evolved from this body; a supposition not in disagreement with sulfur isotopic data. The minerals hosting predominantly CO_2-bearing fluids we suggest were deposited by deep Valles reservoir waters, and the data suggest that two fluids have been active in the VC-2a area in the recent past. (Authors' abstract)

MUSSELWHITE, D.S., SWINDLE, T.D. and DRAKE, M.J., 1988, Mineral/melt partitioning of I: Implications for mantle outgassing (abst.): 51st Ann. Meeting of the Meteoritical Soc., Fayetteville, AR, July 18-22, 1988, Abstracts, p. M-9 (Lunar and Planetary Inst. Contrib. 665). Authors at Lunar & Planet. Lab., Univ. Arizona, Tucson, AZ 85721.

The partitioning of I is pertinent to understanding the distribution of isotopes of Xe. (E.R.)

MUSSMAN, W.J., MONTANEZ, I.P. and READ, J.F., 1988, Ordovician Knox paleokarst unconformity, Appalachians, in N.P. James and P.W. Choquette, eds., Paleokarst: Springer-Verlag, p. 211-228. First author at Total Petroleum, Inc., Denver, CO.

Presents a brief review of the published fluid inclusion data relevant to the Knox paleokarst unconformity. (H.E.B.)

MUTSCHLER, F.E., WILBUR, J.S. and FRIEDMAN, J.D., 1988, Ore sulfides from Shawangunk Mountains, New York, zinc-lead deposits compared with sulfides from MVT deposits (abst.): Geol. Soc. Am., Absts. with Programs, v. 20, p. 57. First author at Dept. Geol., Eastern Washington Univ., Cheney, WA 99004.

Small Zn-Pb-Cu sulfide vein deposits hosted by Silurian orthoquartzites occur in the Shawangunk Mountains of southeastern New York. The Shawangunk deposits share many similarities with other Appalachian, and with Mississippi Valley, Zn-Pb deposits. All are sedimentary rock-hosted and represent open-space filling with a relatively simple ore mineralogy. They are probably of Alleghanian age and may have formed by the movement of connate brines from the interior of sedimentary basins to basin margins. However, Shawangunk ore-brines were somewhat hotter (150°-260°C), but less saline (~10-18 wt.% NaCl eq.) than most MVT ore-brines. Fluid inclusion studies of zoned quartz crystals show that slugs of meteoric water repeatedly entered, and diluted, the connate brines which deposited the Shawangunk ores. Shawangunk ore sulfides exhibit a variety of geochemical differences from MVT sulfides: Shawangunk galenas and chalcopyrites usually have Ag >100 ppm--considerably in excess of all but one MVT district in the eastern U.S. Fe and Ti contents of Shawangunk sphalerites (>4 wt.% Fe, 60-200 ppm Ti) are significantly higher than reported from MVT deposits. Shawangunk sphalerites have lower Cd (300-2000 ppm) and Cd:Mn (~9-40) than MVT sphalerites. Shawangunk sphalerites have very high Hg (50-240 ppm) and locally high Sn (20-80 ppm) compared with most MVT sphalerites. In general, Shawangunk sulfide trace-element chemistries and lead isotope ratios are more akin to southern Appalachian, than to stable interior, MVT sulfides. Shawangunk deposits also share some trace-element and lead isotope characteristics with Mesozoic sulfide deposits associated with border faults of the Newark Series basins. The extent to which these relations reflect source provenance of metals or brine evolution is uncertain. (Authors' abstract)

MYERS, G.L. and MEINERT, L.D., 1988, Zonation of the Copper Canyon-Fortitude gold skarn system (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A93. Authors at Washington State Univ., Pullman, WA 99164.

The Fortitude skarn near Battle Mountain, NV, is currently one of the largest producing Au skarns in the world. It contains approximately 16 million tons (MT) of ore grading 0.15 ounces per ton, and is the distal portion of a continuous skarn system in the Copper Canyon area centered on the Eocene Copper Canyon granodiorite porphyry. Calc-silicate compositions, opaque mineralogy, and the high Au grades are atypical of other base metal skarns (Fe, Cu, Pb-Zn, or W).

The Copper Canyon skarn is systematically zoned from a garnet (AD 70-100) dominant, pyroxene (HD 20-45) subordinate zone, with major Cu mineralization, adjacent to the intrusive (West ore body), to a pyroxene (HD 20-100) dominant, garnet (AD 90-100 cores, AD 30-60 rims) subordinate assemblage, with major Au, near the distal marble front (Fortitude ore body). An extensive biotite ± diopsidic pyroxene ± kspar alteration halo surrounds the pyroxene > garnet Au-bearing skarn and represents the early stages of metasomatic alteration. Retrograde alteration is limited in areal extent and intensity, and consists of actinolite, chlorite, quartz, and prehnite. Economic Au mineralization begins in the pyroxene > garnet zone and continues to the marble front, a distance of 1 to 15 km respectively from the plutonic contact. The opaque mineralogy in this Au zone includes pyrrhotite, arsenopyrite, marcasite, minor chalcopyrite, galena, sphalerite, argentite, hessite, hedleyite, volnyskite, and native bismuth and Au.

Initial FI analyses from calc-silicate phases and quartz (which appears to be nearly contemporaneous with opaque deposition) indicate that the Fortitude Au skarn was formed by lower T and salinity fluids (300-450°C NaCl<<26 wt.%) than the West ore body (T of 450-550°C and salinity >26 wt.%). The arsenopyrite-pyrite-pyrrhotite geothermometer yields T near 300°C at the marble front to about 400°C more proximal to the intrusive. Log fS_2 calculations from the sulfide assemblages yield values near -10 with log fO_2 values of approximately -30, in a solution of near neutral pH (5-6). Calculations of metal solubility suggest that the metals were transported as chloride complexes in the proximal skarn but that bisulfide complexes were predominant within the distal Au skarn. Relatively low oxidation states buffered by the carbonaceous to argilliceous, calcareous protolith and subsequent ferrous iron-rich skarn assemblages appear to have increased the Au carrying capacity of this large hydrothermal system. (Authors' abstract)

MYERS, I.A., GOLDING, S.D. and TAYLOR, R.G., 1988, Oxygen and hydrogen isotope studies of tin deposits associated with a tourmaliniferous granite at Cooktown, North Queensland (abst.): Geol. Soc. Australia Abstract Series No. 21, p. 295. First author at Geol. Dept., James Cook Univ. of North Queensland.

Fluid inclusion studies suggest the mineralizing fluids for both deposits were weakly to moderately saline (2 to 15 wt % NaCl eq.), with T of 400°C for greisen formation, and 300°C to 350°C for the vein system. T of granite formation was ~650°C. Constraints imposed by andalusite formation in the contact aureole and the presence of primary muscovite suggest the Finalyson granite was emplaced at a level of 3.5 to 7.5 kilometers, at 1-2 kb P. (From the authors' abstract)

MYINT, K.M., HOLDEN, G.S. and LEANDERSON, P.J., 1988, Multiple hydrothermal mineralization events, Phoenix vein, Idaho Springs district, Colorado (abst.): Geol. Soc. Am., Abst. with Programs, v. 20, p. 434 and 459. Authors at Dept. Geol. & Geol. Engrg., Colorado Sch. Mines, Golden, CO 80401.

Fluid inclusion data from the Phoenix vein indicates that mineralization in the Idaho Springs district occurred during two separate events, one of Laramide (60 Ma) age and one of significantly younger, possibly Oligocene age. The Phoenix vein, which fills an east-west fracture in Precambrian rocks, is characterized by three discrete mineralization events, separated by fracturing episodes. These events are early quartz-pyrite (Stage I), late quartz-pyrite (Stage II) and base metal (Stage III). The principal ore minerals are pyrite, chalcopyrite, galena, sphalerite and tetrahedrite-tennantite with quartz and carbonate gangue. Native Au occurs in all stages, but Ag only in Stage III sulfosalts.

P fluid inclusions are preserved from Stages II and III only, and in both stages show evidence of boiling at the time of entrapment. Stage II: Th = 290°C (230°-320° range) and contain fluids with salinity from 4.1-6.6 wt% NaCl eq. Stage III: Th = 200°C (180°-300° range) and contain fluids = 6.8-8.4 wt% NaCl eq. Calculated P are 70 bars (850 m depth hydrostatic) for Stage II and 15 bars (150 m depth hydrostatic) for Stage III. The calculated depths suggest a difference in overburden of 700 m between Stage II and Stage III, which is attributed to a long period of erosion. Geomorphic reconstruction suggests that while Stage II is likely of Laramide (60 Ma) age Stage III was significantly younger, possibly associated with Oligocene (40-35 Ma) intrusive activity just west of the Idaho Springs district. (Authors' abstract)

MYSEN, B.O., ed., 1988, Structure and properties of silicate melts: Publ., Elsevier, 1988, ISBN 0-444-42959-X, 368 pp.

Includes a 38-page chapter summarizing the nature and structural roles of H_2O, H_2, S, C, and F in silicate melts. (E.R.)

NAGAYTSEV, Yu.V., 1988, The questions of existing forms and mobilization processes of admixture elements in metamorphic rocks: Vestnik Leningrad. Univ. Geol.-Geograf., 1988, no. 2, p. 7-14 (in Russian; English summary).

Indexed under "Fluid Inclusions." (E.R.)

NARSEEV, A.V., 1987, Fluid conditions during the formation of hydrothermal gold and tungsten vein deposits in thermostatically controlled structures: Petrol. Flyuid.-silikat. Sistem, Novosibirsk 1987, P. 46-56 (in Russian). From Ref. Zh., Geol. 1988, Abstr. No. 4Zh42.

NAUMOV, G.B., SALAZKIN, A.N., MIRONOVA, O.F. and SAVEL'YEVA, N.I., 1987, Methods of studying fluid-inclusion aureoles in prospecting for hydrothermal ores: Geokhimiya, no. 2, 1987, p. 250-259 (in Russian; translated in Geochem.

Int'l., v. 24, p. 83-90). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Abstract in Fluid Inclusion Research, v. 20, p. 280-281. (E.R.)

NAUMOV, V.B., ed., 1987, Inclusions in minerals: Bibliography of Soviet literature (for 1986) and foreign literature (for 1985): Vernadsky Inst. Geochem. & Analy. Chem., 72 pp. (in Russian).

This little volume, printed in an edition of only 300 copies, lists 482 references dealing with fluid inclusions. The first 139 are in Cyrillic, the remainder are all given in English, and do not note the original language. Some entries are from Fluid Inclusion Research. Complete author indices (including those of multiple author articles) are given, but no subject index. (E.R.)

NAUMOV, V.B., 1988a Volatile components in magmatic and metamorphic processes: Fluid and melt inclusion data: Bull. Minéral., v. 111, p. 291-296. Author at Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Kosygin str., 19, 117975, Moscow, USSR.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 281. (H.E.B.)

NAUMOV, V.B., ed., 1988b Inclusions in minerals: Bibliography of Soviet literature (for 1987) and foreign literature (for 1986): Vernadsky Inst. Geochem. & Analy. Chem., 70 pp. (in Russian).

This little volume, printed in an edition of only 300 copies, lists 487 references dealing with fluid inclusions. The first 84 are in Cyrillic, the remainder are all given in English, and do not note the original language. Some entries are from Fluid Inclusion Research. Complete author indices (including those of multiple author articles) are given, but no subject index. (E.R.)

NAUMOV, V.B., SAFONOV, Yu.G. and MIRONOVA, O.F., 1988, Spatial distribution patterns of changes in fluid parameters of the Kolar gold ore deposit (India): Geol. Rudn. Mestorozhd., v. 30, no. 6, p. 105-109 (in Russian). Authors at GEOKhI, Moscow, USSR.

Lenticular Au-quartz bodies of the Kolar (India) Au field occur in a greenschist belt of amphibolites, tholeiitic metabasalts, etc. In the major Champion Reef ore body, Au is associated with scheelite, pyrrhotite, pyrite, sphalerite, galena, etc. Studies indicate a postmagmatic hydrothermal origin of Au ores. The P and S fluid inclusions (FI) in quartz from the ore deposit contain various amounts of CO_2, H_2O, CH_4, etc. With a decrease in depth, the m.p. of the FI decreases from -56.7 to -62.0°; this corresponds to increased content of CH_4 in the fluid. With a decrease in depth, the Th of CO_2 fluids increases from -49.0 to +7.4°, reflecting a decrease in d. A steady change in the composition of the fluid is observed during its ascent to upper horizons; the molar H_2O/CO_2 ratio changes from 1.2 to 13.0. Similarly, the CH_4/CO_2 ratio increases from 0.018-0.024 to 0.32-0.42. The fluid P decreases from 4.9 to 0.7 kbar. A fluid-P gradient of 0.33-6.07 bar/m indicates a deep-seated source for the fluid. (C.A. 110: 216458t)

NAUMOV, V.B., SOLOVOVA, I.P., KOVALENKO, V.I. and RYABCHIKOV. I.D., 1987, Composition, concentration of fluid phase, and water content in pantellerite and ongonite melts based on melt inclusion data in minerals: Dokl. Akad. Nauk SSSR, v. 295, no. 2, p. 456-459 [Petrogr.] (in Russian). Authors at Inst. Geokhim. Anal. Khim., Moscow, USSR.

Melt inclusions with a high-density fluid phase occur in quartz of ongonite-rhyolites from Khetsu-Teg region (Mongolia) and in anorthoclase of pantellerites, ignimbrites, and pumice of Pantelleria (Italy). Residual and homogenized melt (glass) inclusions in quartz and anorthoclase have a high Cl content; the Cl content is 0.69-0.97 wt.% in homogenized melts and is 0.36-0.87 wt.% in residual melts. The concentration of solutions and the Th (166-305°) of fluid phase suggest a d. of 0.85-1.10 g/cm^3 for the fluid phase. The fluid P (2.6-4.3 kbars) and the H_2O content (7.7-12.4 wt.%) in magnetic melts were determined. (C.A. 107: 99991m)

NAVON, O., HUTCHEON, I.D., ROSSMAN, G.R. and WASSERBURG, G.J., 1988, Mantle-derived fluids in diamond micro-inclusions: Nature, v. 335, p. 784-789. Authors at Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125, USA.

Micro-inclusions in diamonds from Zaire and Botswana differ in composition from the more common large inclusions of the peridotitic or eclogitic assemblages. These sub-micrometer inclusions resemble potassic magmas in their composition, but are enriched in H_2O, CO_3^{2-} and K_2O and depleted in MgO. This composition represents a volatile-rich fluid or melt from the upper mantle, which was trapped in the diamonds as they grew. (Authors' abstract)

NEGAHBAN, Shahin, WILLHITE, G.P. and WALAS, S.M., 1988, Modeling of three-phase liquid/liquid equilibria: SPE Reservoir Engrg., v. 3, no. 2, p. 1017-1024.

NEHLIG, P. and JUTEAU, T., 1988, Flow porosities, permeabilities and preliminary data on fluid inclusions and fossil thermal gradients in the crustal sequence of the Semail ophiolite (Oman): Tectonophysics, v. 151, p. 199-221.

Systematic measurements of the orientation and spacing of hydrothermal veins, and sampling for petrological, mineralogical and fluid inclusion studies, have been carried out in the crustal sequence of the Cretaceous Sumail ophiolite, in order to estimate the geometry of the seawater circulation at a fossil spreading center.

Petrological and mineralogical data show that the whole crust, down to the petrological Moho, has been affected by a hydrothermal metamorphism, pervasive in the sheeted dike complex and high-level isotropic gabbros and more localized around fractures in the underlying plutonic units. The sheeted dike complex is overprinted by a greenschist facies metamorphism, whereas the underlying high-level isotropic gabbros are characterized by the association of calcic plagioclase and actinolite (transition facies), retromorphosed in the greenschist facies. Three main types of hydrothermal circulation were distinguished on the basis of field, mineralogical and fluid inclusion studies and analogies with oceanic hydrothermal systems: (1) at the top of the magma chamber, (2) along a cracking front at the transition between a hydrothermal and a magmatic system and (3) off-axis circulation in the whole crust.

Fluids trapped in minerals during their growth or during later fracturing events consist of aqueous solutions with an average salinity close to that of seawater. Th in the stock work zone, underlying the massive ore deposits, are very high, up to 392°C, with no evidence of boiling. T measured in quartz-sulphide veins at the base of the volcanic unit exhibit a large range but are much lower. Furthermore, solutions from the sheeted dike complex exhibit high Tt of ~400°C. These observations are interpreted as reflecting the mixing with cold seawater of solutions exiting the sheeted dike complex. The highest Tt, recorded in the plutonic sequence, are ~500°C, and are assumed to represent accretion-stage circulation occurring directly after crystallization of part or all of the magma chamber. Localized hydrothermal circulation was active until cooing of the whole crust to a geothermal gradient of 30°C/km.

Flow porosities and permeabilities are very high in the upper crust and decrease exponentially with depth, with a major jump at the interface between the volcanic unit and the sheeted dike complex. Furthermore, at this level, the geometric pattern of the circulation changes drastically, evolving from a nearly chaotic system in the volcanic unit to a well-regulated system in the sheeted dike complex and high-level isotropic gabbros, where seawater circulated along vertical planes, parallel to the fossil ridge axis. This geometry in the sheeted dike complex and underlying gabbros suggests that seawater convected essentially along strike in vertical planes, rather than in a cylindrical, transverse system. (Authors' abstract)

See also Nehlig and Haymon, Fluid Inclusion Research, v. 20, 1987, p. 283. (E.R.)

NEHLIG, P., JUTEAU, T., and HAYMON, R., 1988, Fossil metamorphic geothermal gradients in the crustal sequence of the Semail Ophiolite (Oman) (abst.): Abstracts for the Geol. and Tectonics of the Oman Region, Edinburgh, March 29-31, 1988, p.38.

See Nehlig and Haymon, 1987 in Fluid Inclusion Research, v.20, 1987 (E.R.).

NELSON, C.E., 1988, Gold deposits in the hot springs environment: Bulk mineable precious metal deposits of the western United States; Symp. Proc., Reno, NV, USA, Apr. 6-8, 1987, Publ. Geol. Soc. Nevada, 1988, p. 417-431.

Indexed under "Fluid Inclusions." (E.R.)

NERONSKY, G.I. and LEVITSKY, Yu.T., 1988, Gas-liquid inclusions in native gold and their structural position, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 137-140 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 292. (E.R.)

NESBITT, B.E. and MUEHLENBACHS, Karlis, 1988a Deep convection of meteoric water in the continental crust and the origin of quartz veins in greenschist facies rocks (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A44. Authors at Dept. Geol., Univ. Alberta, Edmonton, Alberta, Canada T6G 2E3.

Studies of quartz veins in greenschist facies rocks of the Canadian Cordillera indicate that, contrary to a generally accepted metamorphic origin, the quartz veins originated from large scale convection of ^{18}O-enriched meteoric water. Quartz veins were collected from greenschist facies units from three large regions: Cassiar, northern B.C.; Cariboo, central B.C.; and the Rocky Mountain Trench (RMT). Fluid inclusion studies indicate conditions of formation of 300 ± 50°C and 1 ± 0.3 kbar. Field relations indicate that the veins formed at or shortly after the peak of metamorphism. In the Cassiar district $\delta^{18}O$ values for samples of quartz veins, fall into a relatively tight range of +16 to +19‰. In the Cariboo district values for vein quartz range from +16 to +18% ; however in the adjoining RMT, values are uniformly lower, +11 to +14% . These results document regional homogeneity for $\delta^{18}O$ values of quartz veins and indicate that quartz veins were formed by large scale processes involving relatively homogeneous fluids. Calculated $\delta^{18}O$ values for the vein-forming fluids are 10.0 ± 0.8‰ for Cassiar, 10.5 ± 1.4‰ for Cariboo and 6.2 ± 1.1‰ for

RMT. The quartz veins in the Cassiar region and much of the Cariboo are hosted by altered basalts with $\delta^{18}O$ values in the range of +8 to +11‰. It is apparent that the $\delta^{18}O$ values of the vein fluids are too enriched in ^{18}O to have been derived locally from the host basalts. Average δD values for FI fluids from the quartz veins are -136 ± 5‰ (Cariboo), -145 ± 9.2‰ (RMT), -147 ± 6‰ (Cassiar). The extremely depleted nature of the δD results indicate that meteoric water was a major component of the vein fluid. In order to obtain the enriched $\delta^{18}O$ values, the meteoric water must have interacted with a relatively large rock volume at lower w/r ratios. A model of formation for quartz veins in greenschist facies rocks involves deep convection of meteoric water to the brittle/quasi-plastic transition (~12-15 km) and deposition of quartz veins on the upflow limb of the convection cell. (Authors' abstract)

NESBITT, B.E. and MUEHLENBACHS, Karlis, 1988b, Mesothermal Au ± Ag deposits of the Canadian Cordillera: Evidence for meteoric water involvement in the genesis of mesothermal Au deposits (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 344-346. Authors at Dept. Geol., Univ. Alberta, Edmonton, Alberta, Canada T6G 2E3.

Most geochemical parameters are very consistent from deposit to deposit. Elements associated with mineralization include Ag, As, W, Sb, Hg, and B. Au/Ag ratios are generally greater than 1. Fluid inclusion Th range between 250 and 350°C with CO_2 contents varying from 6 to 100 mol %. The relatively common presence of P inclusions documenting phase separation of CO_2-rich and H_2O-rich fluids indicates that Th data represent Tt. The P(fluid) during entrapment ranged from 700 to 1300 bars. Salinities of the fluids are generally low, varying from 0 to 4 wt % NaCl eq. (From the authors' abstract)

NEUMANN, E.-R., ANDERSEN, T. and MEARNS, E.W., 1988, Olivine clinopyroxenite xenoliths in the Oslo rift, SE Norway: Contrib. Mineral. Petrol., v. 98, p. 184-193. Authors at Mineral.-Geol. Museum, Sarsgt. 1, N-0562 Oslo 5, Norway.

Olivine clinopyroxenite xenoliths in a basalt flow at Krokskogen in the Oslo rift consist mainly of Al-Ti-rich clinopyroxene and alteration products after olivine (possibly also orthopyroxene). The clinopyroxene contains P inclusions of Cr-Al-bearing titanomagnetite, pyrite and devitrified glass, and S fluid inclusions rich in CO_2. On the basis of petrography, mineral compositions and bulk major and trace element chemistry, it is concluded that the xenoliths represent cumulates with about 5% trapped liquid, formed from a mildly alkaline basaltic magma. Microthermometrical analysis of S or PS fluid inclusions give a minimum Pf of 5.5 to 6 kbars, that is a depth greater than 16-17 km. The host lava has initial $\varepsilon_{Nd} = +4.16 \pm 0.17$ and $\varepsilon_{Sr} = -5.50 \pm 0.26$, which is believed to reflect the isotopic composition of the lithospheric mantle source region under south Norway in early Permian time. The isotopic differences [Nd] between the host magma and the xenoliths reflect some degree of crustal contamination of the xenolith's parent magma.

The xenoliths of this study represent an important source of information about the large masses of dense cumulates found at depth in the crust under the Oslo rift. (From the authors' abstract)

NEWBERRY, R.J. and BREW, D.A., 1988, Geology and geochemistry of the Alaska-Juneau (AJ) mine area, Juneau, Alaska (abst.), <u>in</u> Bulk mineable precious metal deposits of the western United States, R.W. Schafer, J.J. Cooper and P.G. Vikre, eds., Symp. Proc., Geol. Soc. Nevada, Apr. 6-8, 1987, p. 741. First author at Dept. Geol., Univ. Alaska.

The AJ mine, 3 miles east of Juneau, Alaska, produced ~ 90 million tons of 1 ppm Au between 1913 and 1944. It is of a non-epithermal origin. The deposit consists of an aggregate of nearly-vertical, quartz ± ankerite-pyrrhotite-pyrite-sphalerite-galena-arsenopyrite-Au veins. The ore-bearing veins are hosted by Triassic graphitic phyllite and Mesozoic amphibolite sills (meta-gabbro) in areas of high sill density. Au is petrographically late and often associated with late carbonate. Petrographic and other fluid inclusion data indicate the fluids were CO_2-rich; this combined with the rare (and late) occurrence of siderite implies that the fluids were initially rich in H_2S and that H_2S concentration decreased with time.

Trace Au studies of the AJ mine area rocks indicate that there are no local highly auriferous sources for mineralization, and consequently we suggest that Au was mobilized by movement of sulfur-rich, reduced, slightly alkaline fluids through the black phyllites and magnetite-rich gabbroic sills. The fluids presumably moved up the local thermal gradient (inverted isograds) due to the regional thermal anomaly caused by the Coast Range Batholith. As the rising fluids were heated by the surrounding rocks, they boiled (suggested by fluid inclusion studies and vein morphologies), sulfur was partitioned into the vapor phase, and Au was released from solution. The simultaneous occurrence of the several factors apparently required for ore formation -- structural focus, CO_2-rich fluids, reduced, S-, and possibly Au-rich rocks, inverted isograds, and broad scale convective movement of water -- is unlikely; thus the AJ mine is probably an uncommon deposit type. (From the authors' abstract by E.R.)

NEWTON, R.C., 1988a, Closepet Granite of south India: Origin by K-metasomatism melting (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A204. Author at Dept. Geophys. Sci., Univ. Chicago, 5734 S. Ellis Ave., Chicago, IL 60637.

Field relations and chemography suggest that the Closepet Granite of southern India was formed by potassium metasomatism of tonalitic/trondhjemitic Peninsular Gneiss. The inferred ion-exhange reaction is:

$$K^+ + \text{biotite} + \text{plagioclase} + \text{quartz} = \text{liquid} + Na^+.$$

Conditions of granite formation were T ~ 750°C, P ~ 5 kbar, $CO_2/CO_2 + H_2O$ (vapor) ~ 0.6 and K^+/Na^+ (vapor) ~ 0.35. The K^+ supplied to the midcrust for metasomatic melting at 2.5 Ga ago is postulated to have come from subsolidus breakdown of biotite and amphibole in the lower crust by rising CO_2-rich solutions of probable subcrustal origin, which could have also supplied heat for melting. The presently-exposed horizon of arrested partial melting corresponds to a transient interface between K-emplacement and K-depletion.

This hypothesis is consistent with 1) the proximity of the southern Closepet to the granulite facies terrain and their depth-zone paleopressure relations, 2) the usually late Archean age of pink migmatite contrasted with the ~ 3.0 Ga age of gray gneiss, 3) the metasomatic (nebulous) aspect of some granite and charnockite, 4) the right-lateral shear zone association of both granite and charnockite, 5) the ubiquitous CO_2-rich fluid inclusions in granite and charnockite, and 6) experimental biotite-quartz melting and feldspar alkali exchange relations.

This explanation ameliorates the classic "room problem" of emplacement of some granites. It is possible that some other post-orogenic leucogranites emplaced in shear zones, such as the late Precambrian granites of western Saudi Arabia, resulted from similar processes. (Author's abstract)

NEWTON, R.C., 1988b, Nature and origin of fluids in granulite facies metamorphism (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 103-105 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 129-131). Author at Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637, USA.

It is likely that different kinds of fluid of different origins and in varying amounts were instrumental in different granulite terrains. Resolution of the nature and extent of the operation of fluids in granulite metamorphism will be provided by detailed studies of oxygen isotopes, oxidation states of iron oxides and silicates, apparent paleofugacities of H_2O and CO_2 indicated by mineral assemblages, and by open-system versus closed-system behavior indicated by metamorphic patterns of major and trace elements. (From the author's abstract by E.R.)

NGUYEN, P.T., 1987, Structural geology and mineralization of the White Devil mine, Tennant Creek, Northern Territory: B.S. thesis, Univ. of Adelaide.

The White Devil Au mine located about 40 km northwest of Tennant Creek, Northern Territory, is currently being developed by Australian Development Limited following a successful exploration program in an area of former mining.

The well-bedded siliciclastic sedimentary rocks of the Lower Proterozoic Warramunga Group, which host the White Devil mineralization, have undergone two main deformations. The early ductile defomation (D_1) was a moderate deformation, which produced upright east-west trending open-close folds, with a regular plunge 40-50° toward 245°. The late semi-ductile to brittle deformation (D_2) was a continuous deformation, which was associated with at least three closely spaced events. These were the intrusion of a set of semi-concordant porphyries, an early east-west upright shearing associated with the emplacement of hydrothermal quartz-magnetite bodies (ironstone) and a progressive shearing associated with the mineralization. The shearing produced a slickenside/fiber lineation, that suggests a vertical-oblique displacement with the south block eastwardly uplifted and the north block westwardly downthrown.

The Au-Bi-Cu mineralization in the White Devil deposit was formed during the progressive deformation (D_2) and was mainly associated with the long thin magnetite-rich bodies and extended in varying degrees into the associated chloritized sediments, especially within the shear zone.

Studies of mineral textures, fluid inclusions, chlorite compositions and sulphur isotopes have provided information of a preliminary interpretation of ore-forming conditions and some indications of evolution of the hydrothermal fluid. Textural relationships and fluid inclusion data demonstrate that there were two distinct phases of the hydrothermal fluid. The magnetite was formed from a fluid of relatively high T (~400°C) and high salinity (probably $CaCl_2$-NaCl). The Au-Bi-Cu mineralization was formed from a fluid of lower T (~300°C) and moderate salinity (probably NaCl-rich). Analyses of chlorite associated with the ore confirm the fluid inclusion T and indicate log fO_2 and log fS_2 conditions of ~ -31.6 to -35.0 and -9.8 to -11.6, respectively. A magmatic component to the fluid is suggested from preliminary sulphur isotope data.

Under the proposed T-fO_2-pH conditions of the fluid, Au transport would be predominantly by means fo the $AuCl^-_2$ complex. Deposition of Au was probably controlled by decrease of fluid T and/or increase in pH. The close association of the ore body and the magnetite suggests that the magnetite may also be an important factor, in that in some way, it could have acted as a chemical trap for the ore deposition. (Author's abstract)

NGUYEN, P.T., BOOTH, S., JAMES, P.R. and BOTH, R.A., 1988, The White Devil gold deposit, Tennant Creek, Northern Territory (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 198-200. First author at Dept. Geol. & Geophys., Univ. Adelaide.

Textural relationships of the ore minerals and studies on fluid inclusions in quartz demonstrate that there were two distinct phases of the hydrothermal fluid involved in formation of the deposit. The magnetite was formed from a fluid of relatively high T (~400°C) and high salinity (probably $CaCl_2$-NaCl). The later Au-Bi-Cu mineralization was formed from a fluid of lower T (~300 to 350°C) and moderate salinity (probably NaCl-rich). Sulphur isotopes suggest a magmatic origin for the sulphur. (From the authors' abstract)

NGUYEN-TRUNG, C., HOVEY, J.K. and TREMAINE, P.R., 1988, Experimental determination of apparent and partial molar heat capacities and volumes of uranyl ions in $UO_2(ClO_4)_2$, $UO_2(NO_3)_2$, UO_2Cl_2 and UO_2SO_4 solutions from 10 to 55°C (abst.): Chem. Geol., v. 70, p. 190. Authors at CREGU, BP 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Apparent and partial molar heat capacities and volumes of uranyl ions in aqueous solutions of $UO_2(ClO_4)_2$, $UO_2(NO_3)_2$, UO_2Cl_2 and UO_2SO_4 have been measured at pH <2 and from 10 to 55°C, using a Picker-type flow microcalorimeter and densimeter. Experimental results were analyzed using Young's rule with the Guggenheim form of the extended Debye-Hückel equation and the Pitzer ion interaction model and related equations. These calculations have led to standard state heat capacities and volumes for the cation UO_2^{2+} and for several of the complexed species from 10 to 55°C. Specific applications of these data in various thermodynamic calculations will be discussed. (Authors' abstract)

NIELSON, D.L. and HULEN, J.B., 1987, Hydraulic fracturing and hydrothermal brecciation in active geothermal systems: Geother. Resources Council, Transactions, v. 11, p. 473-478.

NIEMANN, J.C. and READ, J.F., 1988, Regional cementation from unconformity-recharged aquifer and burial fluids, Mississippian Newman Limestone, Kentucky: J. Sedimen. Petrology, v. 58, no. 4, p. 688-705. First author at Chevron U.S.A., 935 Gravier Street, New Orleans, LA 70112.

[The chemistry and isotopes of] the Mississippian Newman Limestone in Kentucky were studied. [These] may have been subjected to late, postcementation(?) migration of warm fluids based on S fluid inclusions. These late-stage fluids most likely were chemically complex, warm brines (7-17 eq. wt. % NaCl, 50° to 160°C) that resided in the formation for sufficiently short times that conodont CAI values were not affected. (From the authors' abstract by E.R.)

NIKIFOROV, A.S., KASHCHEYEV, V.A., POLUEKTOV, P.P. and POLYAKOV, A.S., 1988, Partially soluble impurity influence of fluid inclusion mobility in halite: Atomnaya Energiya, v. 64, no. 6, p. 453-454 (in Russian; English summary).

NIMTZ, Gunter, MARQUARDT, Peter, STAUFFER, Dietrich and WEISS, Wilfried, 1988, Raoult's law and the melting point depression in mesoscopic systems: Science, v. 242, p. 1671-1672. Authors at Phys. Inst. der Univ. Köln, 5000 Köln 41, FRG.

Data on the melting point depression in small In or Au particles and in liquid water held between lipid bilayers indicate that these systems obey Raoult's law, with the surface atoms or molecules acting like solute particles in a dilute solution. (Authors' abstract)

NISHRI, A., HERBERT, H.J., JOCKWER, N. and STICHLER, W., 1988, The geochemistry of brines and minerals from the Asse salt mine, Germany: Applied Geochem., v. 3, p. 317-332. First author at IOLR, Tel-Shikmona, Haifa 31080, Israel.

The chemistry and stable isotopes (^{18}O, D) of highly concentrated chloride brines and minerals from the Asse salt mine in the north of the Federal Republic of Germany were studied. Chemical data indicate the occurrence of three types of brines: (a) Mg-Cl type, of carnallitite origin with Li <30 mg/kg; (b) Na-Cl type brines, of rock salt origin, with Li >100 mg/kg; and (c) almost pure $MgCl_2$-type brines wtih Li >100 mg/kg. The first group may be subdivided into brines with Li <4.0 mg/kg and brines with Li between 18 and 30 mg/kg. Li is shown to be an efficient complementary tool in tracing the origin of the brines. The complex evolution of carnallitite-type brines is discussed in detail. Isotopic data of brines that were sampled directly from seepages (presumably unaltered) indicate that these brines are not a mixture with relatively fresh ground water from the overburden sediments. The stable isotope composition (^{18}O and D) of hydration water in carnallite, kieserite and polyhalite sampled from the Asse mine were also studied. It is shown that water extracted from the so-called primary carnallite is isotopically different from water extracted from secondary carnallite. The isotopic fractionation factors for ^{18}O and D between carnallite hydration water and mother solution were studied in the laboratory. Assuming the crystallization water of the so-called primary carnallite samples is not altered, the isotopic composition of the mother solution is evaluated. (Authors' abstract)

NIVIN, V.A., 1988, Distribution of microinclusion gases in the ore horizons of the Lovozero Massif, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 222-228 (in Russian).

NIVIN, V.A., KAMENSKIY, I.L. and TOLSTIKHIN, I.N., 1988, Helium and argon isotope compositions in rocks of the ore horizons of the Lovozero massif: Geokhimiya, no. 1, p. 33-39 (in Russian; translated in Geochem. Int'l., v. 25, no. 8, p. 27-32, 1988). Authors at Geol. Inst., Kola Br., USSR Acad. Sci., Apatity, USSR.

He and Ar isotope compositions in Lovozero rocks have been determined in order to characterize the volatile components characteristically occurring there. An MI 1201 mass spectrometer has been used. Specimens for the ore complex were studied in which the inclusion gases extracted on crushing had previously been analyzed. It is found that the He is mainly radiogenic. The juvenile component is most prominent in He from gas microinclusions. The $^{40}Ar/^{36}Ar$ ratios in the Ar trapped by the rocks are close to the atmospheric value, and the proportion of Ar relative to the radiogenic component is not more than 10. There are regularities in the inert-gas and isotope-ratio distributions in the rocks of the ore horizons, which can be used to detect economic mineralization. (Authors' abstract)

NOBLE, D.C. and ALVAREZ, A.A., 1988, Purisima Concepcion, a Te-rich sediment-hosted disseminated precious-metal deposit associated with a high fO_2 and fS_2 porphyry system (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A92. First author at Mackay Sch. Mines, Univ. Nevada-Reno, Reno, NV 89557.

Sediment-hosted disseminated Au ores very similar to those of "Carlin-type" deposits of the western U.S. are present at Yauricocha, central Peru.

The Purisima Concepcion deposit is situated in the core of a plunging anticline several hundred meters beyond large pipe-shaped Cu-Zn-Pb-Ag-Au replacement ore bodies in limestone bordering a K-silicate altered late Miocene granodiorite stock.

Enargite, tetrahedrite and high-S Cu-sulfide minerals in the replacement ores and of pyrophyllite, diaspore, alunite, anhydrite, and high-T compositionally complex high-salinity FI in altered rocks bordering enargite veins in the stock, and the intense dissolution of the limestone host suggest that the fluids that deposited the polymetallic ore bodies had low pH and high fO_2 and fS_2. The magmatic-hydrothermal system was similar to that of Julcani and other enargite-tetrahedrite districts in Peru, with the differences in ore types largely reflecting the carbonate host. The chemistry of the Purisima ores can be qualitatively explained by hydrothermal differentiation. Precipitation of base-metal and Ag sulfides and sulfosalts depleted the fluids in these components and produced a decrease in Cu/Zn, Cu/Pb, As/Sb, base/precious metal, and Ag/Au ratios. The moderate pH and low fO_2 and fS_2 implied by mineral assemblages presumably reflects carbonaceous material.

Similar deposits can be expected elsewhere in the Western Cordillera where hydrothermal fluids related to Neogene stocks encountered impure limestone of the Cretaceous Pariatambo and Jumasha Formations. Certain sediment-hosted disseminated Au-Ag deposits elsewhere may be have a similar genetic relation to porphyry, skarn, and(or) stock-related replacement system. (From the authors' abstract by H.E.B.)

NOISIK, L.P., REKHARSKY, V.I., IGNAT'EVA, I.B. and SEROVA, L.S., 1988, Carbon in minerals, *in* Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 241-247 (in Russian).

NORMAN, D.I., 1988, Proceedings of the first annual meeting of the Pan-American current research on fluid inclusions group: Geochim. Cosmo. Acta, v.52, p.969. Author at Dept. Geol. Sci., New Mexico Tech., Socorro, NM 87801, USA.

A review of the history leading up to the PACROFI meeting Jan., 1987, and the plans for future meetings. (E.R.)

NORMAN, D.I. and CROWLEY, Nanolivia, 1988, Modeling deposition of Au-Ag-base metal deposits based on fluid inclusion data (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A352. Authors at Dept. Geosci., New Mexico Tech., Socorro, NM 87801.

A program, GEOMOD, has been developed that calculates solubility of precious metals, base metals, iron and silica. Input data is the gaseous species, T, and salinity of the ore solution from fluid inclusion analysis. The program permits modeling of the change in solubilities resulting from boiling, mixing, and cooling processes, and yields data such as vertical extent of a favorable zone, metal ratios, and grade of mineralization.

The modeling program successfully allows one to predict from fluid inclusion analyses the types of metals that would be deposited in a geothermal system. It explains the classic mineral zonation in boiling epithermal systems (base metal-Ag-Au), explains why H_2S contents of ore fluids >0.01% are necessary to form Au ore bodies, and that bonanza Au deposits best form from open system boiling of solutions with H_2S >0.1%. Application of the modeling program to fluid inclusions data from well studied deposits like St. Cloud, NM, explains the change in Ag/Au from bottom to top of the ore bodies from ~ 1000 to ~ 30, and at Cochiti, NM, successfully predicts the vertical extent of the favorable zone. For Comstock, NV, the program indicates the vertical extent of the bonanza ore shoots, and why they formed at T of 250° to 270°C from 300°C fluids.

The data suggest that fluid inclusion data from a few well chosen samples from a hydrothermal deposit can indicate the potential for ore-grade mineralization and nature of the ore. (Authors' abstract)

NOVGORODOV, P.G nad BULANOVA, G.P., 1988, Melt inclusions in eclogitic diamonds: International symp. on composition and processes of deep-seated zones of continental lithosphere, Novosibirsk, 30 May-2 June, 1988, p. 148-149. Authors at Inst. Geol., Yakutsk, USSR.

Syngenetic microinclusions similar in composition and properties to partly crystalline melt inclusions have been found in situ as zonally distributed inclusions in three eclogitic diamonds, using electron probe and molecular microanalyses. The absence of cracks reaching the diamond surface, restriction of inclusions to definite growth zones of the host and their unusual composition provide evidence for their P origin.

A partly crystalline melt inclusion consisting of rutile, clinopyroxene, and K-Al-Si and Fe-Ti-Si phases has been identified centrally located in an octahedral single crystal diamond from the Mir pipe. The two latter phases have characteristic features of solidified melts of contrasting compositions and contain also S, P and Cl. The bulk composition of the inclusions is consistent with hypersthene andesite: SiO_2 = 57 to 60, Na_2O = 1.5, K_2O ~2.7, TiO_2 = 4 to 7 wt% (Bulanova et al., 1988). The clinopyroxene is compositionally distinct from isolated omphacite inclusions found in the same crystal. The omphacites correspond to pyroxenes of rutile eclogite associations (Sobolev et al., 1983). A T range of diamond crystallization estimated using equilibrium garnet-omphacite assemblages (Ellis, Green, 1979) from the central and marginal parts of a diamond crystal at P = 50 kb is 1210° to 1190°C, respectively.

20 inclusions of a potassic phase with $mK_2O \cdot nNa_2O \cdot Al_2O_3 \cdot 6SiO_2$ ($m + n < 1$, $m > n$) composition, one sanidine inclusion, one rutile inclusion, eight coesite inclusions, six omphacite inclusions and one sulphide inclusion represented by a troilite-chalcopyrite intergrowth have been studied in an octahedral coated diamond (Mir pipe). Inclusions of the potassium-bearing phase are characterized by variable alkali contents, the Al_2O_3 to SiO_2 ratio ~ 1/6; the TiO_2 content varies between 1 to 2 wt%; FeO, CaO and MgO contents are very low; these potassic phases invariably contain P and Cl and also perhaps other dissolved volatiles. A thin film of disordered graphite is always present at the boundary between the inclusions and the diamond. Raman spectra of the inclusions show that, depending on alkali contents, they are a polycrystalline aggregate of potassic feldspar or a solidified melt (glass).

The melt inclusions studied appear to characterize the subliquidus evolutionary stage of mantle eclogites. Melt of andesitic composition with a calculated T of 1210°C (P = 50 kb) is probably a fragment of initial melting of rutile eclogites, whereas a high-K melt represents its final evolutionary stage. A high-K melt is somewhat similar compositionally only to acid liquation products of lunar and terrestrial basalts (Roedder, 1983; Ryabov et al., 1985) differing from them by even lower FeO, MgO and CaO contents. (Abbreviated from the authors' abstract by E.R.)

For translation of full paper, see Bulanova et al., this volume. (E.R.)

NOVGORODOVA, M.I., PETROVSKAYA, N.V. and BOYARSKAYA, R.V., 1988, Daughter crystals of gas inclusions in native metals, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings:

Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 69-75 (in Russian).
Note - This may be the same paper, from the Seventh All-Union Conference on Thermobarometry, the abstract of which was translated in Fluid Inclusion Research, Vol. 19, 1986, p. 316-317. (E.R.)

NOVOTNÝ, P. and SÖHNEL, O., 1988, Densities of binary aqueous solutions of 306 inorganic substances: J. Chem. Eng. Data, v. 33, p. 49-55. Authors at Chemopetrol, Res. Inst. of Inorganic Chem., Revoluční 86, 400 60 Ússtí nad Labern, Czechoslovakia.

Constants of equations expressing the density of binary aqueous solutions as a function of concentration, and where possible also of T, are given for 306 inorganic substances. The goodness of fit and limits of the equation validity are indicated for each system. (Authors' abstact)

NTAFLOS, Th., KURAT, G., BRANDSTÄTTER, F. and TOURET, J., 1986, Zabargad Island peridotites: Hydrothermal activities within the upper mantle beneath the Red Sea: Int'l. South European Symp. on Explor. Geochem., IGME-AEG, 9-11 Nov. 1986, Athens, Greece, Programme with Abstracts, p. 46. First author at Naturhistorisches Museum, A-1014, Vienna, Austria.

Zabargad (St. John's) Island is located near the central trough of the northern Red Sea at about 23° 36,5' N, 36° 12' E and contains three ultramafic bodies. The peridotites are divided into three groups, the primitive, depleted and metasomatized.

The primitive peridotites are sp-lherzolites, sp-plag-lherzolites and plag-amph-lherzolites and have major and trace element composition which approach the estimated upper mantle composition. The relative REE abundances are flat at 2XCl, or slightly depleted in the LREE.

The depleted peridotites are mainly sp-harzburgites and some dunites and have low HREE abundances and low La/Yb ratios. The metasomatized peridotites are tectonically sheared and show a steep REE pattern with LREE up to 55XCl and HREE 2XCl. For this contamination a fluid rich in REE and especially in LREE must have been responsible. This is supported by the halogen contents which are factors of 10-100 times higher than the halogen contents of ultramafic xenoliths. The primitive Cl/J[Cl/I?] ratios indicate derivation of the fluids from the Earth's mantle. All samples have Ir/Au ratios within the range of typical upper mantle rocks with higher absolute concentrations of Ir than Au; basalts and crustal rocks always show the reverse. Veins are abundantly present in Zabargad Island peridotites. They are mainly monomineralic, from sheetlets and sheets (mostly between cm's and dm's in thickness) and include olivinites (which are the parent rocks for the famous gem olivine), orthopyroxenites, clinopyroxenites, websterites, hornblendites and plagioclasites.

The Zabargad vein rocks are apparently of "hydrothermal" origin. These rocks are monomineralic dikes with mineral grain sizes far exceeding that of magmatic rocks and they are rich in fluid inclusions. They are of a hypersaline character, are H_2O-free, and are dominated by CO_2. The REE contents of all the monomineralic rocks are compatible with the experimental data on CO_2-rich fluids in equilibrium with silicate system. Fluids are oversaturated in a single phase under given P-T and activity conditions, in contrast to silicate melts which are oversaturated on several phases.

Formation of vein rocks is closely associated with tectonization as are the metasomatic alterations. Such processes could also be responsible for the origin of other monomineralic rocks like phlogopitites, garnetites and chromitites. (Authors' abstract)

NURMI, P.A., KUKKONEN, I.T. and LAHERMO, P.W., 1988, Goechemistry and origin of saline groundwaters in the Fennoscandian Shield: Geochimica Cosmo. Acta,

v. 52, p. 185-203. Authors at Geol. Survey of Finland, SF-02150 Espoo, Finland.

Chemical and isotopic analyses of water from drill holes and mines throughout the Fennoscandian Shield show that distinct layers of groundwater are present. An upper layer of fresh groundwater is underlain by several sharply differentiated saline layers, which may differ in salinity, relative abundance of solutes, and O, H, Sr and S isotope signature. Saline groundwater can be classified into four major groups based on geochemistry and presumed origin. Brackish and saline waters from 50-200 m depth in coastal areas around the Baltic Sea exhibit distinct marine chemical and isotopic fingerprints, modified by reactions with host rocks. These waters represent relict Holocene seawater. Inland, three types of saline groundwater are observed: an uppermost layer of brackish and saline water from 300-900 m depth; saline water and brines from 1000-2000 m depth; and superdeep brines which have been observed to a depth of at least 11 km in the drill hole on the Kola Peninsula, U.S.S.R. Electrical and seismic studies in shield areas suggest that such brines are commonly present at even greater depths. The salinity of all inland groundwaters is attributed predominantly to water-rock interaction. The main solutes are Cl, Ca, Na and Mg in varying proportions, depending on the host rock lithology. The abundance of dissolved gases increased with depth but varies from site to site. The main gas components are N_2, CH_4 (up to 87 vol.%) and locally H_2. The $\delta^{13}C$ value for methane is highly variable (-25 to -46‰), and it is suggested that hydrothermal or metamorphic gases trapped within the surrounding rocks are the most obvious source of CH_4. The uppermost saline water has meteoric oxygen-hydrogen isotopic compositions, whereas values from deeper water plot above the meteoric water line, indicating considerably longer mean residence time and effective low T equilibration and host rocks. Geochemical and isotopic results from some localities demonstrate that the upper saline water cannot have been formed through simple mixing between fresh water and deep brines but rather is of independent origin. The source of water itself has not been satisfactorily verified although superdeep brines at least may contain a significant proportion of relict Precambrian hydrothermal or metamorphic fluids. (Authors' abstract)

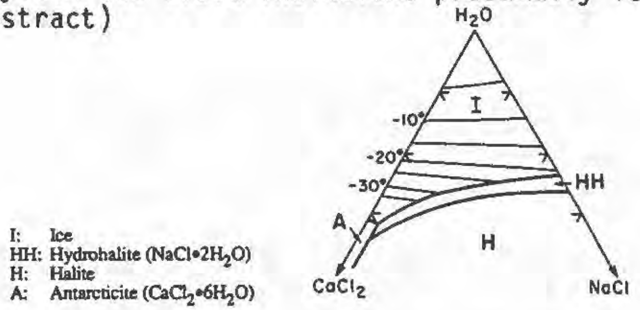
NYMAN, M.W. and BODNAR, R.J., 1988, Microscale fluid immiscibility associated with late stage tectonic events, SE Adirondacks: Evidence from fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A100-A101. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Large quartz segregations associated with late (Paleozoic?) faults, diabase dikes, and pegmatitic quartz-feldspar-biotite veins in the southeast Adirondacks postdate peak metamorphism. Secondary FI in these quartz pods are of three types: (Type 1) high density CO_2 inclusions which outline well-healed fractures and occur in irregular clusters; (Type 2) regularly shaped, brine inclusions which occur along well-healed fractures and postdate Type 1 inclusions; (Type 3) large, irregular brine inclusions with large vapor bubbles and variable homogenization (Th) and ice-melting T and trapped along late, poorly healed fractures. Where fractures containing Type 1 and Type 2 inclusions cross, mixed brine + CO_2 inclusions occur in the vicinity of the fracture intersection. Mixed CO_2-brine inclusions decrepitate at ~280°C (before Th is reached) and, therefore, the solvus crest in the H_2O-CO_2-NaCl system for these FI has a minimum T of 280°C. This T is consistent with the greenschist facies retrograde assemblage observed in metagabbro xenoliths which are found within the quartz pods and cut by all the fracture sets. Continued next page.

Two phase inclusions containing variable amounts of brine and CO_2 (5-20 vol. % brine) observed at fracture intersections suggest the presence of two immiscible fluids. However, the mixed brine + CO_2 inclusions in these samples are observed only at the intersection of two fractures of unknown but different ages. This suggests that fluid immiscibility was not operating on a regional, outcrop or even thin section scale but, rather, on a microscale of tens to hundreds of microns. Inclusions with variable phase ratios and compositions, coexisting with end member inclusions which appear to have been trapped at the same time, are often reported as evidence of fluid immiscibility in metamorphic rocks. Many of these studies report that the mixed inclusions occur at fracture intersections; often no details are reported concerning the presence of mixed inclusions in isolated clusters or along individual fractures. These observations suggest that fluid immiscibility during medium to high grade regional metamorphism may be less common than FI data indicate. Mineral equilibria, uplift paths, and isochores calculated assuming fluid immiscibility may be significantly affected. (Authors' abstract)

OAKES, C.S., BODNAR, R.J. and SIMONSON, J.M., 1988, Phase equilibria in the system $NaCl-CaCl_2-H_2O$: The ice liquidus (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A390. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Vapor-saturated phase relations in the ice-stable field of the system $NaCl-CaCl_2-H_2O$ have been determined from the depression of the freezing point. Freezing points were determined along the two binaries and along four pseudobinaries for concentrations between 3 wt% total salt and the cotectic. 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 in the $CaCl_2-H_2O$ binary and $NaCl-CaCl_2-H_2O$ ternary. Eutectic T 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 pont depression 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 hydrohalite and ice-melting T in fluid inclusions using previously published freezing point data cause errors as large as 2 wt%. Similarly, $NaCl/(CaCl_2 + NaCl)$ ratios estimated from previously published data may be in error by X(NaCl) = 0.15. Our results eliminate apparent compositional inconsistencies between brines produced from the Salton Sea Geothermal System and fluid inclusions presumably formed from those brines. (Authors' abstract)



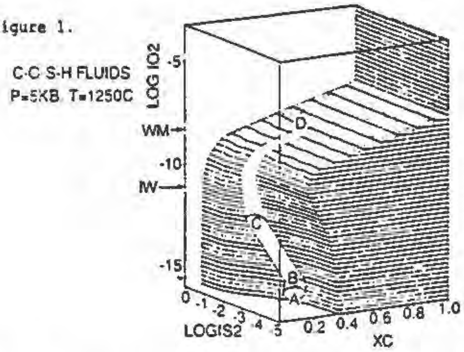
ODLING, N.W.A., 1988a Synthetic high temperature, high pressure fluid inclusions - A new technique (abst.): Geol. Soc. Australia Abstract Series No. 21, p. 299-300. Author at Dept. Geol., Univ. Tasmania. Continued next page.

Using the experimental technique of Sterner and Bodnar (Fluid Inclusion Research, v. 17, p. 331-332, 1984, but not so cited), a buffer assembly and an organic fluid source, secondary fluid inclusions were made at 15-35 kb and 1175-1250°C, in olivine and quartz, with a range of CH_4-H_2O ratios (± CO_2). Compositions were checked by mass spectrometry and Fourier transform IR spectrometry. Hydrogen diffusion out of the inclusions apparently changed gas compositions. (E.R.)

ODLING, N.W.A., 1988b, C-O-S-H fluids - Redox reactions as a mineralization mechanism in layered mafic intrusions (abst.): Geol. Soc. Australia Abstract Series No. 21, p. 297-298. Author at Dept. Geol., Univ. Tasmania.

A model has been developed to account for the non-ideal nature of fluids at high T and P. The results are plotted in an isobaric, isothermal diagram, in which the effects of oxidation, reduction and carbon saturation on fluid composition are illustrated. Point A represents an initial reduced fluid composition composed mainly of CH_4, H_2 and minor H_2S. At this point platinoids may have been present as chloride complexes as Cl partitioned into the evolved fluid/melt. As crystallization of the footwall cumulates proceeded the residual melt would have become increasingly enriched in volatile components and as a consequence the sulphur fugacity rose though not enough to stabilize either base metal or PGE sulphides (point B). Once the fluid mixed with the overlying oxidized magma it will quickly [become] oxidized and saturated in carbon (points C-D). With this oxidation the fluid chemistry changed dramatically from being CH_4-H_2-H_2S dominated to a mixture of H_2O and CO_2. This process has several important consequences ... Fluid inclusions should form during periods of fluid saturation and could prove a valuable exploration tool. As only the four component system C-O-S-H has been studied, the inclusion of Cl to the system would be a useful addition for future work. (From the author's abstract by E.R.)

Figure 1.



O'DONOGHUE, Michael, 1988, Gemstones: Chapman and Hall, London, 372 pp.

Chapter One (17 p.) presents a discussion--not illustrated-- of the formation and the occurrence of fluid and solid inclusions in gemstones. (H.E.B.)

OELKERS, E.H. and HELGESON, H.C., 1988a, Prediction of dissociation constants and limiting equivalent conductances of triple ions in high-temperature hydrothermal solutions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A96. Authors at Dept. Geol. & Geophys., Univ. California, Berkeley, CA 94720, USA.

Calculation of accurate mineral solubilities in hydrothermal solutions requires dissociation constants for the predominant aqueous complexes. Calculation of Gibbs free energy changes resulting from the electrostatic interaction of aqueous species at high T and low P, where the dielectric constant of H_2O is <10, indicates that triple ions such as $NaCl_2^-$ and Na_2Cl^+ are the major species in concentrated alkali metal halide solutions under these conditions. The thermodynamic and transport properties of 28 alkali metal halide triple ions at high T and P were computed from the revised HKF equation of state for aqueous species (Tanger and Helgeson, 1988) together with dissociation constants and predicted equation of state parameters generated from equations and coefficients given by Fuoss and Krauss (1933), Shock and Helgeson (1988), Oelkers and Helgeson (1988a), and Sverjensky et al., (1988). The logarithms of the calculated dissociation constants for triple ions (log K) at 750 bars decrease from ~1.00 to ~ -2.5 with increase T from 300° to 800°C. Distribution of species estimates generated using these log K values and those for the dissociation of 1:1 ion pairs (Oelkers and Helgeson, 1988b), together with activity coefficients of charged and neutral species (Helgeson et al., 1981; Oelkers and Helgeson, 1986), indicate that triple ions predominate in low-P supercritical solutions in ionic strengths greater than ~1.0 m. Under these circumstances, mixed complexes such as $KNaCl^+$, $MgKCl_2^+$, $ZnNaCl_2^+$, $FeKCl_2^+$, Na_2SCl^-, etc., may have a substantial effect on the hydrothermal solubilities of minerals at high T and low P where many geochemical processes occur. (Authors' abstract)

OELKERS, E.H., and HELGESON, H.C., 1988b, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Aqueous tracer diffusion coefficients of ions to 1000°C and 5 kb: Geochim. Cosmo. Acta, v.52, p.63-85.

O'HANLEY, D.S., SCHANDL, E.S., and WICKS, F.J., 1988, Time relationships between alteration and deformation at the Slade-Forbes asbestos deposit, Deloro Township, Ontario (abst.): GAC/MAC Program with Abstracts, v.13, p.A92. Authors at Royal Ontario Museum, Dept. of Miner. , 100 Queen's Park, Toronto, Ontario, M5S 2C6.

Preliminary analysis of alteration and deformation at the Slade-Forbes asbestos deposit outlines a complex but discernible history. Two generations of talc-carbonate are recognized based on texture and mineralogy. The earlier event produced fine-grained carbonate mesh rims with talc mesh centers and preserved the magnetite formed during the previous serpentinization. The later event produced coarse-grained talc, carbonate and sphene after the first talc-carbonate event. Fluid inclusion data indicates a Tf of 300-350°C for the second talc-carbonate event. Sporadic late-stage formation of talc after carbonate and antigorite after talc indicates that the activity of CO_2 decreased after deformation. (From the authors' abstract)

O'HARA, Kieran, 1988, Contrasting styles of deformation in two adjacent quartzofeldspathic mylonite zones, western Blue Ridge, NC - The important role of the quartz feldspar (Q/F) ratio (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A332. Author at Dept. Geol. Sci., Univ. Kentucky, Lexington, KY 40506.

The southern margin of the Hot Springs window, NC, is bounded by the Rector Branch (RB) mylonite zone and the subparallel Meadow Fork (MF) mylonite zone. Field, petrographic and chemical data indicate that the RB mylonites were derived from the surrounding gneisses whereas the MF rocks represent mylonitized quartzofeldspathic sediments. The different protoliths are reflected in the different physical and chemical parameters of the two mylonite zones. The mean free path (MFP) refers to the average distance (mm) between feldspar grains.

	SiO_2	Al_2O_3	Q/F	MFP	Feldspar
Rb	63%	14%	0.42-0.53	0.2 -0.7	Poorly sorted/angular
MF	80%	9%	0.7 -0.73	0.58-0.60	Well sorted/subrounded

These data are consistent with the observation that feldspar in the RB mylonites underwent grain size reduction by cataclasis whereas feldspar in the MF mylonites "floats" passively in a quartz matrix. Grain-size reduction of feldspar in the RB mylonites was a precursor to its chemical breakdown to white mica, resulting in reaction-enhanced softening.

In contrast, strain in the MF zone was largely accommodated by quartz deformation. Quartz displays a strong c-axis texture but also contains numerous oblique healed microfractures defined by fluid inclusion trails. Fluid densities, inferred from Th (150-220°C) are consistent with the T of mylonitization based on metamorphic grade and microstructure (300-350°C). Quartz in the MF mylonites apparently deformed semibrittly. Freezing studies (T(last melt): -14 to -19°C) indicate the fluids were highly saline (18-22 wt% NaCl eq.). The fluid phase may have promoted hydrolytic weakening and/or stress corrosion cracking in quartz. The Q/F ratio was also important in determining the relative importance of creep, cracking and chemical reaction in the mylonites. (Author's abstract)

OHBA, Takeshi and MATSUO, Sadao, 1988, Precise determination of hydrogen and oxygen isotope ratios of water in fluid inclusions of quartz and halite: Geochem. J., v. 22, p. 55-68. First author at Kusatsu-Shirane Volcano Observatory, Tokyo Inst. Tech., Kusatsu, Agatsuma, Gunma 377-17, Japan.

A vacuum ball mill was devised to extract volatiles from fluid inclusions in minerals. A special feature of the crushing mode is the horizontal oscillation of the mill, which enhances crushing efficiency and overcomes the fragility of the mill, which is made by Pyrex glass. This ball mill is equipped with a cold finger trap cooled with LN_2 to reduce the influence of adsorption of once extracted volatiles on a mineral powder during the crushing process.

Amounts and isotope ratios were determined for water extracted from the fluid inclusions of quartz and halite. The determinations were made for CO_2 as well in fluid inclusions of quartz. The influence of adsorption on amounts and isotopic ratios of volatiles was evaluated by comparing the results of repeated extractions with and without the liquid nitrogen trap during the crushing process. In a single run of extraction, two kinds of water were obtained: one was water trapped in the cold finger trap during the crushing, the other was desorbed water given by heating of the sample after crushing. A simple summation of the isotope ratios of the desorbed and the trapped waters gives an erratic result in comparison with the original isotope ratio. As for the fluid inclusions in hydrothermal quartz, the original $\delta^{18}O$ and δD values for water in the inclusions can be estimated by applying Rayleigh's equation to the adsorption process. In the case of halite samples, however, the estimation of the original $\delta^{18}O$ and δD values is much more difficult because of the formation of hydrate salts. However, in the special case where the brine in inclusions is a pure NaCl solution, the original inclusion water is simply the sum of the desorbed and trapped waters.

For CO_2 analysis of inclusion fluids, the adsorption during the crushing process is negligibly small, not affecting appreciably the results on $\delta^{13}C$ and $\delta^{18}O$ values. (Authors' abstract)

OLSEN, S.N., 1988, High-density CO_2 inclusions in the Colorado Front Range: Contrib. Mineral. Petrol., v. 100, p. 226-235. Author at Dept. Earth & Planet. Sci., The Johns Hopkins Univ., Baltimore, MD 21218, USA.

A fluid density in an inclusion is commonly observed to be too low for the P-T estimates for the postulated time of trapping, and is generally attributed to a fluid loss during the uplift process. It is more difficult to explain a fluid density which is too high. In the 1700 m.y. Front Range migmatites, such high densities occur in some of CO_2 inclusions which were deduced to have formed during the migmatization episode. The peak P-T estimates from migmatization in the Front Range are 4-6 kb and 650°-700°C (in sillimanite field) but P required to form the most dense inclusions are >7.6 kb (in kyanite field). The high density is not likely to be a relic of a higher P condition earlier than the main migmatization episode for the following reasons: (a) no kyanite (or any other relic high P phase) has been found in the Precambrian Front Range; (b) the high density inclusions are rare in zones with least signs of deformation and melting (paleosomes and quartz inclusions within feldspar grains) which instead contain relatively undisturbed early inclusions; (c) high density inclusions with Th < -30°C are associated with heavily altered plagioclase caused by hydrothermal activity which was a late event in leucosome formation. Further, there is evidence for post-entrapment change(s) in density: an intragranular trail in quartz contains CO_2 that exhibit almost the whole range in Th (-40 to +24°C) as displayed by the entire population of the early CO_2 inclusions (-66 to +30°C). The density of an inclusion in the trail is not related to inclusion size but to the position of the inclusion relative to apparent micro-shear zones crossing the CO_2 trail. A change to a higher density (= a smaller volume) could have resulted from an initially isobaric cooling path which intersects CO_2 isochores with increasingly higher densities. Additional excess P may have resulted from overthrusting. However, because high density inclusions occur selectively in the zones in which plagioclase shows alteration indicating a high aH_2O and because there is a correlation between shear zones and high density inclusions, it is postulated that local hydrolytic weakening of quartz was necessary for the decrease of inclusion volume which occurred during deformation. The localized deformation may also result in an excess P. However, the introduction of a small amount of H_2O into these inclusions as a possible cause of high density inclusions cannot be ruled out. (Author's abstract)

O'REILLY, S.Y., and GRIFFIN, W.L., 1988, Mantle metasomatism beneath western Victoria, Australia: I. Metasomatic processes in Cr-diopside lherzolites: Geochem. Cosmo. Acta, v.52, p.433-447. First author at School of Earth Sci., Macquarie Univ., Sydney, N.S.W. 2109, Australia.

Most Cr-diopside spinel lherzolite xenoliths from Bullenmerri and Gnotuk Maars, western Victoria, show modal metasomatism involving the growth of amphibole ± mica ± apatite at the expense of primary pyroxenes + spinel. The metasomatism is attributed to CO_2-rich fluids, observed in fluid inclusions. (From the authors' abstract)

ORESKES, Naomi and EINAUDI, M.T., 1988, Origin of LREE-enriched hematite breccias at Olympic Dam, Roxby Downs, South Australia (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A143. Authors at Geol. Dept., Stanford Univ., Stanford, CA 94305.

Hematite breccias are the host rocks to over two billion tons of Cu-U-Au-Ag mineralization at the world class Olympic Dam deposit. The deposit consists of ramifying breccia dikes within a fractured granite host and is zoned from weakly brecciated, sericite- and hematite-altered granite on the margins, through heterolithic breccia, to hematite-quartz microbreccia in the center. This zonation documents a progressive mechanical brecciation and iron metasomatism of the granitic wall-rock. Fe-metasomatism occurred by hematization of feldspar and sericite in altered and brecciated granite, as well as by in-filling of fractures by hematite. Early breccia and vein components were fragmented and incorporated into later breccias. We interpret the breccias to be the result of catastrophic hydraulic brecciation and fluidization accompanied by intense hydrothermal alteration of granite. This is in marked contrast to previous interpretations, which described the Olympic Dam breccias as alluvial fans deposited along graben margins.

The hematite breccias are highly enriched in both light and heavy REEs, with typical La values of 10^3 - 10^4 x chondrite. ΣREE and La/Lu increase with the proportion of hematite in the breccia. Black-scattered electron imaging and EDS analysis have identified five hydrothermal REE phases: bastnaesite, florencite, monazite, xenotime, and britherite. They occur in all breccia types and in a variety of habits: disseminated in quartz-sericite matrix of granitic breccia, in quartz-sericite veins, interstitial to hematite laths, intergrown with barite, and as inclusions in hematite and sulfide grains. The abundance of REEs in hydrothermal phases, extreme REE enrichment of the breccias relative to unaltered wall rock, concentration of REEs in the center of the hydrothermal system, and variable slopes of chondrite-normalized patterns attest to extensive mass transport and hydrothermal deposition of REEs in the fluids responsible for mineralization and breccia formation. Preliminary phase equilibrium and FI studies suggest that these fluids were of moderate T, oxidized, and relatively rich in F, Cl, and CO_2. (Authors' abstract)

ORTIZ HERNÁNDEZ, L.E. and SOLÍS PICHARDO, G.N., 1986, Mineralogy and paragenesis of the gold-silver breccias of the San Martin mine, Municipio de Colon, Qro: Boletín de Mineral., v. 2, no. 1, p. 1-12 (in Spanish; English abstract).

The Au-Ag mineralization in the San Martin mine occurs in breccia pipes caused by collapse and hydrothermal activity. Concordant, tabular structures caused by hydrothermal brecciation are also present. Host rocks are limestones, shales and marls of the Soyatal-Mexcala Formation (Upper Cretaceous). Ore minerals are electrum, aguilarite, naumannite, freibergite and argentite; gangue minerals are quartz and calcite. These hypogene minerals were formed in four stages. Fluid inclusion microthermometry in calcite showed Th between 150°-275°C and salinities of 1.39-3.05 wt.% eq. NaCl. The last mineralizing stage is supergene, as evidenced by the presence of embolite, acanthite, bromirite [bromargyrite]-cerargyrite, chalcedony, and calcite. (Authors' abstract)

OSBORN, W.L., McKIBBEN, M.A. and WILLIAMS, A.E., 1988, Formation, diagenesis and metamorphism of lacustrine sulfates under high geothermal gradients in an active continental rift zone (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A51. Authors at Dept. Earth Sci. & Geothermal Resources Program IGPP, Univ. California, Riverside, CA 92521.

The Salton Trough of southern California 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 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 and repeated cycles of basin filling and desiccation 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 up to 350°C at only 3.2 km depth in areas near geothermal fields.

New drill cores recovered by the 3.2 km-deep Salton Sea Scientific Drilling Project provide data on the evolution of lacustrine sulfates upon burial and heating. Euhedral to lenticular gypsum is precipitated within the sediments at or near the aqueous or aerial interface and undergoes dehydration to anhydrite at 80-105°C and depths of 225-250 m. FI in gypsum contain 5-10 wt % eq. NaCl fluids; upon dehydration these fluids are diluted, forming inclusions in nodular anhydrite that contain <4 wt % eq. NaCl fluids. This implies that gypsum dehydration occurs by a solution-precipitation process in a hydrologically closed system. No intermediate sulfate phases have been observed. With further burial and recrystallization the inclusion compositions approach those of the reservoir geothermal fluids (20-26 wt % eq. NaCl), implying open-system behavior.

An upward-regressional continental sabkha depositional setting is implied by sulfate structures. Disseminated nodular anhydrite in laminated silty shales or storm washover sediments occurs to depths of 1.6 km. Below 1.6 km, anhydrite occurs as bedded gypsum pseudomorphs or as massive beds in laminated shales.

FI Th indicate that the sulfates are in thermal equilibrium with the present elevated geothermal gradient, undergoing progressive increase in grain size with depth and T. Replacement of anhydrite by carbonate occurs below 1 km, and replacement by epidote and amphibole occurs in isolated zones below 1.3 km. (Authors' abstract)

OSIF, T.L., 1988, The effects of salt, gas, temperature, and pressure on the compressibility of water: SPE Reservoir Eng., v.3, no.1, p.175-181.

Laboratory measurements of compressibilities are presented that show that plots of the reciprocal of compressibility vs. P are linear for water and brines. The slopes of these plots are all the same, but the intercepts are linearly dependent on the T and the salinity over the range of conditions studied (1,000 to 20,000 psi [6.9 to 138 MPa], 200 to 270°F [93.3 to 132°C], and 0 to 200 g/L). Dissolved gas has no effect on these compressiblities at gas/water ratios (GWR's) of 13 scf/bbl [2.3 std m^3/m^3]. Even at GWR's of 35 scf/bbl [6.3 std m^3/m^3], dissolved gas probably has no effect, but certainly causes no more than a 5% increase in the compressibility of brine. (Author's abstract)

OSORGIN, N.Yu., PAL'YANOV, Yu.N., SOBOLEV. N.V., KHOKHRYAKOVA, I.P., CHEPUROV, A.I. and SHUGUROVA, N.A., 1987, Liquefied gas inclusions in diamond crystals: Dokl. Akad. Nauk SSSR, v. 293, no. 5, p. 1214-1217 (in Russian; translated in Trans. Acad. Sci. USSR, Earth Sci. Sects., v. 293, no. 2, p. 150-153, 1988). First author at USSR Acad. Sci.

Large (≤200 μm) primary inclusions in synthetic diamond were found to contain a single fluid phase consisting of liquid H_2, N_2 and CO (gas chromatography of gases from heating at 400, 1100 and 1200°C in He). Crushing stage (sapphire anvils) showed 1200- to 1500-fold expansion, corresponding to 10 kb pressure at room T(sic). Slower growth yielded faceted negative crystal cavities. Some inclusions also contained masses of metallic catalyst. (E.R.)

OSTAPENKO, N.S., LEVITSKII, Yu.T. and SHAKHRAI, S.A., 1988, Evaluation of the temperature of decrepitation of minerals in thermobarometry, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 228-238 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 306. (E.R.)

OWEN, L.B., TORONTO, T.W. and PETERSON, R.E., 1988, Reliability of anelastic strain recovery estimates for stress orientation in the Travis Peak Formation, Harrison County, Texas: Soc. Petrol. Eng. of AIME, Proc. Ann. Tech. Conf., p. 597-603.

Indexed under "Fluid Inclusions." (E.R.)

OZIMA, Minoru and ZASHU, Shigeo, 1988a Noble gas diffusion in diamonds (abst.): EOS, v.69, p.511.

OZIMA, M. and ZASHU, S., 1988b Solar-type Ne in Zaire cubic diamonds: Geochim. Cosmochim. Acta, v. 52, p. 19-25.

OZIMA, M., ZASHU, S., TAKIGAMI, Y. and TURNER, G., 1988, 6 Ga ^{40}Ar-^{39}Ar 'age' of Zaire cubic diamonds: Pre-solar or excess ^{40}Ar (abst.): Lunar & Planet. Inst. Symp. on Origin of the Earth, Berkeley, CA, Dec. 1-3, 1988, LPI Contribution No. 681, p. 63-64.

PAAR, W.H. and RAINER, Peter, 1988, Tertiary gold-quartz mineralizations of the "Tauerngoldgang" type, Austria (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 332-335. First author at Univ. Salzburg (Geosci.), Hellbrunnerstr. 34, A-5020 Salzburg, Austria.

Preliminary studies of fluid inclusions of vein quartz associated with the Au mineralization indicate T formation ranging from ~180°C (in some metasediment environments) up to 350°C (but <470°C) for gneiss-hosted mineralizations. (From the authors' abstract)

PABALAN, R.T. and PITZER, K.S., 1988a Heat capacity and other thermodynamic properties of Na_2SO_4(aq) in hydrothermal solutions and the solubilities of sodium sulfate minerals in the system $Na-Cl-SO_4-OH-H_2O$ to 300°C: Geochimica Cosmo. Acta, v. 52, p. 2393-2404.

PABALAN, R.T. and PITZER, K.S., 1988b Models for aqueous electrolyte mixtures for systems of limited concentration and for systems extending from the dilute range to the fused salt - Evaluation of parameters to high temperatures and pressures (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Authors at Dept. Chem. & Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720.

Models based on general equations for the excess Gibbs energy of the aqueous fluid provide thermodynamically consistent structures for evaluating and predicting aqueous electrolyte properties. These equations yield other quantities upon appropriate differentiation, including osmotic/activity coefficients, excess enthalpies, heat capacities, and volumes. For systems of limited concentration the most commonly used is the Pitzer ion-interaction model. For these systems various experimental data extending upwards in T and P exist from which model parameters can be evaluated. Examples of these evaluations are given, with applications to predictions of mineral solubilities in mixed electrolytes. For more concentrated solutions including those extending to the fused salt, an alternate model is presented which is based on a Margules-type expansion commonly used for nonelectrolyte solutions and which has been previously tested on some ionic systems. Evaluation of literature values on some geologically relevant electrolytes shows that this model accurately describes the thermodynamic properties of aqueous electrolytes to high T's and P's from dilute concentration to the fused salt. (Authors' abstract)

PALINKAS, L.A., 1988, Fluid inclusion studies in Ljubija siderite mine in NW Bosnia (Yugoslavia) (abst.): Chem. Geol., v. 70, p. 14. Author at Mining-Geol.-Petroleum Engrg. Fac., Univ. Zagreb, Pierottijeva 6, 41000 Zagreb, Yugoslavia.

Ljubija mine is a huge siderite deposit in Permo-Carboniferous sedimentary rocks with scanty interstratified volcanics in NW Dosnia. The ore occurs as stratiform or cross-cutting vein-like bodies in clastics, or as large masses in Middle Carboniferous carbonate rocks. The deposit was formed during early intracontinental rifting. Increased thermal gradient, deep open fractures and implacement of volcanics generated thermal plums [plumes] whose width is approximately 20 km, gradually passing into domains of ore-districts Trgovska Gora in Croatia. Chemical character of circulating hydrothermal water was mostly NaCl, less frequently KCl, $CaCl_2$, and $FeCl_2$. Salinity ranges from few to several tens of wt.% NaCl eq. and Th from 100 to 300°C approximately. Ore body in zone locality (nearby Ljubija) originates from the two-phase region of the hydrothermal convective cell, and Ljubija ore deposit from it lower margin. The depth of formation determined on a basis of PT parameters of boiling fluids is between 200 and 500 m, depending whether lithostatic or hydrostatic P is engaged. The Permian siderite-barite deposits along the margin of the Mesozoic carbonate platform demarcate future opening of the Tethys. They may be followed from Central Bosnia, Slovenia to Rudabanya (Hungary), Rudnyani (ČSSR) and Eastern Alps. There is a slight shift in formation time in concordance with delay in opening. (Author's abstract)

PANAGIOTOPOULOS, A.Z., WILLSON, R.C. and REID, R.C., 1988, Phase equilibria in ternary systems with carbon dioxide, water, and carboxylic acids at elevated pressures: J. Chem. Eng. Data, v. 33, p. 321-327.

PANDYA, N., MUENOW, D.W., and SHAMRA, S.K., 1988, Calibration of a micro-Raman multichannel Raman spectrometer for geochemical analyses (abst): EOS, v.69, p.500.

PANIAGUA, Andres, LOREDO, Jorge and IGLESIAS, J.G., 1988, Epithermal (Cu-Co-Ni) mineralization in the Aramo mine (Cantabrian Mountains, Spain): Correlation between paragenetic and fluid inclusion data: Bull. Minéral., v. 111, p. 383-391. First author at Dept. Geol.-Univ. Arias de Velasco, S/N. 33005 Oviedo, Spain.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 301-302. (H.E.B.)

PANINA, L.I., PROSHENKIN, I.E. and BULGAKOVA, E.N., 1987, Formation of rocks of the Khaninsky Massif (the Aldan shield) according to study of chemical characteristics of melt inclusions: Geol. & Geophysics, 1987, no. 8, p. 50-62 (in Russian; English abstract).

Study of melt inclusions in rock-forming minerals has shown that the formation of rocks and apatite mineralization in the Khaninsky Massif had most probably occurred in the process of mixing two equally hot (up to ≈1300°C) melts of contrasting composition: alkaline-basaltoid and low-silica-carbonaceous(?). Moreover certain evidence suggests possible liquation of alkaline basaltoid magma into two constituents. Minerals crystallization was accompanied by fractionation and as the result the composition of residual liquor changed in the direction of decreasing the content of Si, Al, Mg, alkalies almost to their complete disappearance. The greatly fractionated residuum is close to calcite melt in composition. (Authors' abstract)

PANINA, L.I., PROSHENKIN, I.E., BULGAKOVA, E.N. and USOLTSEVA, L.M., 1987, Khaninsky Massif of ultrabasic-medial rocks and its genesis (the Aldan shield): Geol. & Geophysics, 1987, no. 6, p. 39-49 (in Russian; English abstract).

The geological structure of the Khaninsky Massif, composed of biotite ultrabasic-medial rocks is discussed. Chemical composition of rocks and minerals is given. It is noted for high-magnesian femic minerals and orthoclase enriched in Ba and Sr. It is established that the formation of rock-making minerals, including apatite and water-bearing biotite and amphibole, occurred in magmatic melts as early phases of crystallization enriched by CO_2 and at later phases by H_2O. High content of CO_2 in melt has resulted in high T of minerals crystallization: pyroxene - 1300-1210°C, apatite - 1290-1240°C, orthoclase - 1260-1240°C. Attention is paid to the similarity in chemical composition and T of crystallization of minerals in the Khaninsky Massif and ultrapotassium alkaline massifs and also alkaline basaltoids of potassic specialization. Both may originate from source magma of similar chemical composition, while ways of their crystallization being slightly different. (Authors' abstract)

PANTER, K.S. and CAMPBELL, A.R., 1988, A fluid inclusion study of ore and gangue minerals; implications to genetic relationships, Saint Michael's Mount, Cornwall, England gold skarn system (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A93-A94. Authors at Geosci. Dept., New Meixoc Inst. Mining & Tech., Socorro, NM 87801.

The Saint Michael's Mount granite hosts tungsten-tin mineralization in sheeted veins. The major gangue and ore minerals are quartz, wolframite and cassiterite. Previous FI studies of this area (Jackson and Rankin, 1976; Moore and Moore, 1979) found Th values for inclusions in cassiterite to be significantly higher than those in the "intergrown" quartz. This raises questions regarding FI studies of seemingly cogenetic minerals.

The infrared microscope enables measurement of FI in visibly opaque wolframite. Texturally, wolframite is complexly intergrown with quartz and is associated with cassiterite. Inclusions in quartz and wolframite are dominated by a liquid-rich, two-phase type. Small unidentified dms have been observed in quartz, but are absent in wolframite.

Th values for wolframite range from 351° to 399°C with mean of 369°C. Salinities average 4.2 eq. wt.% NaCl. Inclusions in quartz have Th values from 263° to 374°C and average 311°C. Salinities average 7.3 eq. wt.% NaCl.

Comparison of the previous data from cassiterite with the new data from wolframite suggests that these two minerals were deposited at approximately the same T (370°C), which is about 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. Certainly at Saint Michael's Mount, the assumption that inclusions in quartz are representative of inclusions in associated ore minerals is not valid. (Authors' abstract)

PARKS, G.A. and POHL, D.C., 1988, Hydrothermal solubility of uraninite: Geochimica Cosmo. Acta, v. 52, p. 863-875.

PARLAKTUNA, Mahmut and OKANDAN, Ender, 1988, Effect of carbon dioxide on PVT behavior of water below 150°C: Geother. Resources Council, Transactions, v. 12, p. 131-136. Authors at Middle East Tech. Univ., Petroleum Engrg. Dept., 06531 Ankara, Turkey.

Natural hydrothermal systems usually contain appreciable concentrations of non-condensable gases, especially carbon dioxide. Presence of CO_2 causes the transition between single-phase and two-phase flow to happen deeper in the well bore than one would expect when CO_2 is ignored.

PVT experiments for water-carbon dioxide binary system were conducted with carbon dioxide concentrations of 0.30, 1.36, 1.97 and 2.26% by weight at three different T namely 103, 123 and 146°C and the flashing P of the system was observed to see the increase with the increase of carbon dioxide concentration and/or T, as expected. An empirical equation was derived for the partial P of carbon dioxide as a function of T and carbon dioxide concentration in liquid phase for the T interval of 103-146°C. (Authors' abstract)

PARMAN, Lynn, 1988, Thermal maturity of Carboniferous strata around the Ozark Dome: MS thesis, Univ. Missouri, Columbia, MO, USA, 92 pp.

Indexed under "Fluid Inclusions." (E.R.)

PARRY, W.T., WILSON, P.N. and BRUHN, R.L., 1988, Pore-fluid chemistry and chemical reactions on the Wasatch normal fault, Utah: Geochimica Cosmo. Acta, v. 52, p. 2053-2063. Authors at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112, USA.

Mineral assemblages and fluid inclusions (F.I.) in hydrothermally altered and tectonically deformed Oligocene quartz monzonite in the footwall of the active Wasatch normal fault, Utah, have been used to estimate fluid P, T, chemical composition, and chemical reactions associated with progressive displacement of the fault.

Vein filling and pervasive alteration mineralogy includes (earliest to latest) biotite-K-feldspar, chlorite-epidote-sericite, and laumontite-prehnite-clay. Secondary F.I. in quartz, associated with chlorite-epidote-sericite alteration, consist of CO_2 and salt solution; the Th mode is 285°C, $X(CO_2)$ is 0.03-0.32, and salinity ranges from 4.5-17.3 wt.% NaCl eq.; estimated minimum entrapment P vary from 600-2950 bars. The Th mode of S F.I. associated with the laumontite-prehnite assemblage is 100°C, salinity ranges from 2.0-16.0 wt.% NaCl eq., and no CO_2 was detected; entrapment P are presumed to have been hydrostatic and below 460 bars.

Fluid P and T evolved along a path from lithostatic to hydrostatic with continued displacement of the footwall relative to the hanging wall. Age constraints are provided by a 17.6 ± 0.6 m.y. K-Ar age of hydrothermal sericite from a sample with mean Th of 309°C, and 7.3 to 9.6 m.y. fission track ages of apatite (closure T $120 \pm 15°C$).

Calculated equilibrium phase diagrams illustrate the systematic variation in cation activities, CO_2 fugacity, and alteration minerals as fluid T and P decrease. The ratios of $aCa^{2+}/(aH^+)^2$ and $aMg^{2+}/(aH^+)^2$ increase and the ratio aK^+/aH^+ decreases by more than two orders of magnitude each as T decreases and alteration mineralogy changes from K-feldspar and muscovite to muscovite and clay.

The hot aqueous fluids affect the mechanical behavior of the rock during faulting. Crack sealing by alteration product minerals reduces permeability, and the effective stress is decreased by pore fluid P substantially greater than hydrostatic in the early alteration. (Authors' abstract)

PASAL'S'KA, L.F.*, KALINICHENKO, A.M., MATYASH, I.V. and BAGMUT, M.M., 1988, Diagnostics of organic materials in minerals: Dopovidi Akad. Nauk Ukrayins'koyi RSR, Ser. B: Geol., Khim. ta Biol. Nauki, 1988, no. 9, p. 25-27 (in Ukrainian; English summary).

Indexed under "Fluid Inclusions." (E.R.) *Probably should be PASAL'SKAYA. (E.R.)

PASAL'SKAYA, L.F., KALINICHENKO, A.M., MATYASH, I.V. and PROSHKO, V.Ya., 1988, A study of the composition of the fluid phase of inclusions by PMR and gas-chromatography, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 80-85 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 194 (under Kalinchenko, et al.). (E.R.)

PASCAL, M.L. and ROUX, J., 1988, Influence of (K, Na)Cl on the solubility of Fe in hydrothermal chloride solutions (500-700°C) (abst.): Terra cognita, v. 8, p. 72-73. Authors at CRSCM, la rue de la Férollerie, 45071 Orléans Cedex 02, France.

Fe-Mg partitioning between hydrothermal chloride solutions and minerals (olivine, opx, biotite, spinel ...) have been investigated by achieving ion-exchange isotherms between $FeCl_2$-$MgCl_2$-H_2O fluid and olivine and/or opx, with a bulk Cl concentration varying from 0.2 m to 4 m and adding KCl or NaCl to the solution. The isotherms are not affected by the variation of the bulk Cl concentration, which rules out any major influence of $MgCl_2$ and $FeCl_2$ ionization constants on the mixing properties of the fluid. The presence of KCl or NaCl considerably increases the Fe/Mg ratio of the fluid in equilibrium with a given composition of mineral, without changing the bulk Fe + Mg content of the fluid. This increase of the Fe-concentration due to (K, Na)Cl has been further investigated by measuring the solubility of hematite-magnetite assemblages into KCl-H_2O fluids, buffering aHCl by the conventional Ag-AgCl method. At 600° and 2 kbars, the Fe concentration increases from 0.3 m in pure water to 1.1 m in a 2-molal KCl solution. (From the authors' abstract)

PASTERIS, J.D., 1988c Secondary graphitization in mantle-derived rocks: Geology, v. 16, p. 804-807. Author at Dept. Earth & Planet. Sci., Washington Univ., Box 1169, St. Louis, MO 63130.

The assemblage magnesite + "graphite" ± CH_4 has been identified by laser Raman microprobe spectroscopy in fluid inclusions in olivine grains in the Kao kimberlite and the Duluth Complex troctolite. In both cases, the assemblage (essentially Eggler's EMOG oxygen-fugacity buffer) is believed to arise from secondary reactions rather than from primary igneous processes. The known stability field in P-T-fO_2 space of the EMOG buffer, coupled with some other petrologic constraints imposed by the host rocks, indicates in both cases that the carbon-bearing assemblage was precipitated at low P and T ($\leq$ 2 kbar, $\leq$ 550°C) at oxygen fugacities within about 1 log (fO_2) unit below the fayalite-magnetite-quartz (FMQ) buffer. The laser Raman microprobe provides compositional and structural data on the coexisting phases (including carbon) that further constrain the stability field of the natural assemblages. (Author's abstract)

PASTERIS, J.D., 1988b [Methane inclusion in anhydrite]: EOS, v.69, no.21 p.611.

A 400-μm inclusion of low-P methane (≈1 bar) in an anhydrite crystal embedded in halite from the Weeks Island salt dome, Louisiana, and nearby high-P methane (≈130 bars) inclusions in halite are shown on cover photograph. Analyses by laser Raman microprobe show CH_4 + $\leq$4 mole % CO_2. (E.R.)

PASTERIS, J.D. and WANAMAKER, B.J., 1988a Laser Raman microprobe analysis of experimentally reequilibrated fluid inclusions in olivine: Some implications for mantle fluids: Am. Mineral., v. 73, p. 1074-1088. First author at Dept. Earth & Planet. Sci. & McDonnell Center for Space Sci., Washington Univ., Box 1169, St. Louis, MO 63130, USA.

Polished wafers of San Carlos olivine, containing fluid inclusions, were heat treated at T up to 1400°C at oxygen fugacities within the stability field of Fo(90), that is, approximately between the fayalite-magnetite-quartz and iron-wüstite buffers. The $f(O_2)$ was controlled by appropriate mixtures of H_2 and CO_2 or CO and CO_2. Analysis by microthermometry (MT) and laser Raman microprobe (LRM) showed all of the FI to consist of pure CO_2 before the experiments were performed. However, when these same inclusions were checked by MT after 1 to 161 h of heat treatment, melting-point depressions (cf. -56.6°C for pure CO_2) were observed. The lowest final melting T, about -63.5°C, were recorded for samples treated at the lowest $f(O_2)$ values. LRM analyses showed many of these reequilibrated inclusions to consist of mixtures of CO and CO_2, ranging from trace CO to 44 ± 5 mol% CO. The inclusions treated at the lowest $f(O_2)$ values also contain moderately well crystallized graphite, as revealed by LRM analysis, but not detectable optically. Rapid reactions obviously have occurred among (1) the initially high-$f(O_2)$, pure-CO_2 FI, (2) the natural olivine with its inherent Fe^{2+} - Fe^{3+} ratio and defect abundance, and (3) the reducing H_2-CO_2 and CO-CO_2 mixtures in the furnace gas. Clearly, oxidation-reduction and diffusion are involved in the reequilibration. The rapidity of the reactions seems to rule out ionic diffusion, including pipe diffusion along dislocations. The most likely mechanism of reequilibration involves the diffusion of metal vacancies (point-defect diffusion) within the host olivine. Changes in defect concentrations in the solid, in response to the externally imposed $f(O_2)$, resulted in the transfer of oxygen from the inclusion fluid to the surrounding solid. This transfer resulted in the production of CO: $2CO_2 = 2CO + O_2$. The precipitation of graphite in the lowest-$f(O_2)$ experiments is significant in that the combined reactions $CO_2 = C + O_2$ and $2CO = CO_2 + C$ prevented the inclusion fluid from exceeding about 42 mol% CO, even though the predicted compositions were up to 90 mol% CO (considering only the equilibrium $2CO_2 = 2CO + O_2$). In other words, the inclusions became internally buffered along the CCO buffer. The rapid reequilibration of FI (and their host minerals) suggests the unlikelihood of detecting trapped fluids whose compositions represent early magmatic proceses deep in the upper mantle. It also suggests that some further cautions are required in the interpretation of "inherent" mineral characteristics such as defect concentrations and intrinsic oxygen fugacity. (Authors' abstract)

PASTERIS, J.D. and WANAMAKER, B.J., 1988b, Analysis of experimentally reequilibrated fluid inclusions in mantle olivine by laser Raman microprobe and microthermometry (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 65. First author at Dept. Earth & Planet. Sci., Washington Univ., St. Louis, MO 63130.

San Carlos olivines, containing fluid inclusions initially of pure CO_2, were heat-treated as high as 1400°C at fO_2s within the stability field of Fo_{90}, i.e., approximately between the QFM and IW buffers. The fO_2 was controlled by appropriate mixtures of H_2 and CO_2 or CO and CO_2. Analyses were made by microthermometry (MT) and laser Raman microprobe (LRM) on fluid inclusions treated 1-161 hrs. MT analyses showed compositional changes even after only 1 hr. LRM analyses showed that reequilibrated inclusions (regardless of composition of furnace gas) consist of mixtures of CO and CO_2, from trace to 44 ± 5 mole % CO. Reequilibration probably involved diffusion of metal vacancies (point-defect diffusion) in the olivines. Inclusions that fully equilibrated outside the field of graphite stability have CO-CO_2 ratios consistent with the T and fO_2 of the furnace and the internal pressures inside the fluid inclusions (5-10 kb). Inclusions treated at the lowest fO_2s contain, in addition, well crystallized graphite, as revealed by LRM analysis, but not detected optically. Graphite precipitation is significant in that the combined reactions $CO_2 = C + O_2$ and $2CO = CO_2 + C$ internally buffered the fluids along the CCO buffer. Thus, in the low-fO_2 runs, inclusion compositions are ~42 mole % CO, even though the predicted compositions (disregarding graphite stability) are ~90 mole % CO. Rapid reequilibration of fluid inclusions seems to preclude preservation of trapped fluids whose compositions represent early magmatic processes in the upper mantle. It suggests further cautions in interpretation of "inherent" mineral characteristics such as defect concentrations and intrinsic oxygen fugacity. This study also demonstrates how readily graphite may precipitate from C-O-bearing fluids. (Authors' abstract)

PASTERIS, J.D., WOPENKA, Brigitte and SEITZ, J.C., 1988, Practical aspects of quantitative laser Raman microprobe spectroscopy for the study of fluid inclusions: Geochim. Cosmo. Acta, v. 52, p. 979-988. First author at Dept. Earth & Planet. Sci. & McDonnell Center for Space Sci., Washington Univ., Box 1169, St. Louis, MO 63130, USA.

This paper is addressed to both geologists who use laser Raman microprobe (LRM) spectroscopy to analyze fluid inclusions and to those who want to evaluate analyses done by this technique. Emphasis is on how to obtain quantitative analyses of fluid inclusions. We discuss the basic method of fluid inclusion analysis by LRM spectroscopy and the levels of accuracy and precision attainable with this technique. We evaluate which kinds of fluid inclusions and host mineral matrices will yield the most reliable compositional data. Necessary sample preparations, detection limits, problems with fluorescence, dependence of Raman scattering efficiencies on density, and many other questions asked at the workshop on Raman spectroscopy during the 1987 ACROFI meeting also are addressed. The complementary nature, advantages, and disadvantages of both LRM spectroscopy and microthermometry, the two techniques most frequently used for the analysis of individual fluid inclusions, are emphasized.

Some discussions are intended to help LRM users calibrate, and evaluate the optical characteristics of their particular instruments. It is hoped that this paper will further LRM users in finding a common ground on which to discuss the differences and similarities among different LRM instruments and that it will encourage a future consensus on efficient means of calibration and on interlaboratory standards. (Authors' abstract)

See corrections published in same journal, v. 53, p. 215, 1989. (E.R.)

PATEL, M.R. and EUBANK, P.T., 1988, Experimental densities and derived thermodynamic properties for carbon dioxide-water mixtures: J. Chem. Eng. Data, v. 33, p. 185-193. Authors at Dept. Chem. Engrg., Texas A&M Univ., College Station, TX 77843.

Vapor-phase densities have been measured for mixtures of 2, 5, 10, 25, and 50 mol % water in carbon dioxide by using a Burnett-isochoric apparatus. These experimental densities, which cover a T range from 323.15 to 498.15 K and a P range from 27 kPa to 10.34 MPa, are considered accurate to ±0.05%.

Thermodynamic properties, derived from the experimental data for all five mixtures, have also been reported along with the corresponding P-enthalpy diagrams. (Authors' abstract)

PATERSON, C.J., UZUNLAR, Nuri and LONGSTAFFE, F.J., 1988, A view through an epithermal-mesothermal precious metal system in the northern Black Hills, South Dakota, U.S.A.: A magmatic origin for the ore-forming fluids (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 383-385. First author at Dept. Geol. & Geol. Engrg., South Dakota Sch. Mines & Tech., Rapid City, SD 57701, USA.

Fluid inclusions in quartz and fluorite from veinlets in these deposits are diverse. Most have low salinity (<10 wt%), but saline fluids (15-63 wt% eq. NaCl) occur deeper in the system and in the intrusion-hosted deposits. Dms of halite and sylvite have been identified. The gradation in fluids from high-T, high-salinity to moderate-T, low-salinity suggests a mixing of fluids, which may also have caused deposition of Au. Although there are considerable T ranges within single deposits (especially intrusion-hosted), Tt are consistently high (450-500°C) deep in the system, but decrease abruptly over a short vertical distance in the vicinity of the unconformity. Tt in the sediment-hosted deposits above the unconformity are in the range 170-260°C. (From the authors' abstract)

PATERSON, M.S., 1988, The role of water in quartz deformation (abst.): Terra cognita, v. 8, p. 73. Author at Research Sch. Earth Sci., Australian National Univ., Canberra 2601, Australia.

The modes of incorporation of water in quartz have been clarified considerably in recent years, leading to clearer ideas about the role of water in dislocation flow in quartz. A hierachy of three groups of water-related species appear to be involved at different scales: (1) molecular water aggregates serving as reservoirs of water and sometimes providing dislocation sources, (2) species in solid solution promoting diffusion, and (3) species in dislocation cores facilitating glide mobility. In the light of this picture, three regimes of flow can be defined with increasing T and water fugacity or decreasing strain rate: (1) an intrinsic regime of extremely high strength not involving water; (2) a glide control regime in which water has in some degree reduced the Peierls barrier; (3) a recovery control regime in which the Peierls barrier is negligible and the flow is rate-controlled by recovery processes mainly involving dislocation climb. The basic role of water in the second and third regimes is to promote diffusion of oxygen and/or silicon. (Author's abstract)

PATIL, R.R., SHARMA, Rajesh and GUPTA, K.R., 1988, On the nature of sphalerite mineralization from Darabi, Teshil Riasi (Jammu & Kashmir): Geoscience J., v. 9, no. 1, p. 1-12. First author at Wadia Inst. Himalayan Geol., Dehra Dun.

The paper deals with the ore mineralogical and fluid inclusion studies of sphalerite mineralization in Darabi area, district Udhampur, J. & K. The ore minerals are found in the form of veins, lenticles, pockets, and breccia fillings in the Great Limestone of Jammu Himalaya. The colored sphalerites of this area are predominantly found associated with calcite and baryte gangue. The other ore minerals which are confined to some structurally weaker zones include pyrite, chalcopyrite and pyrrhotite. The study was carried out to understand the nature of mineralization and the fluids responsible for the ore deposition. The textural evidence support the hydrothermal origin of the mineral deposit which is also substantiated by fluid inclusion studies carried out during present investigation. Three genetic types of fluid inclusions have been recognized, namely primary, secondary and pseudosecondary. The biphase primary inclusions suggest low saline and warm nature (268-310°C) of hydrothermal fluid responsible for mineralization. It is further evidenced that the mineralization is deposited in at least two phases. In the first phase of mineralization predominance of Zn sulphides is observed while the later phase was enriched in Cu and Fe sulphides. (Authors' abstract)

PATTRICK, R.A.D., BOYCE, A. and MacINTYRE, R.M., 1988, Gold-silver vein mineralization at Tyndrum, Scotland: Min. & Petrol., v. 38, p. 61-76. First author at Dept. Geol., The University, Manchester, England.

Electrum, hessite, petzite and sylvanite have been recorded from veins at Tyndrum, Scotland. Electron probe micro-analyses have also revealed two unnamed Ag-Te-S phases. Fluid inclusion studies suggest that the mineralizing fluids responsible for the precious metal mineralization contained

~7.0 mol % CO_2 and 7 wt % NaCl. Th (temperature of homogenization) determinations were in the range 295°C to 325°C and a depth of vein formation ~4 km is indicated. Mineral precipitation was probably caused by cooling and adsorption of Au onto pyrite. $\delta^{34}S$ values of +1.8‰ for galena from the Au + AG + Te veins suggest a different (possibly igneous) sulphur source to that producing the Pb + Zn vein mineralization in the Tyndrum area. Although an age of ~380 Ma was obtained using K-feldspar in the veins the data are not conclusive. It is argued that the Au + Ag mineralization at Tyndrum is due to hydrothermal activity related to Cu + Mo mineralization associated with the Late Caledonian granites. (Authors' abstract)

PAUSHKIN, Ya.M., ZHOROV, Yu.M., LAPIDUS, A.L. and GORLOV, Ye.G., 1988, Hydrocarbons from CO_2 and H_2: Dokl. Akad. Nauk SSSR, v. 298, no. 2, p. 374-377 (in Russian). Authors at Inst. Mineral Fuels, Moscow, USSR.

The paper presents synthesis conditions of hydrocarbons from carbon dioxide and hydrogen, e.g., $xCO_2 + yH_2 \rightarrow CxHy + 2xH_2O$ at 423 to 473 K, 1.5-2.0 MPa with a Ni, Fe, Co catalyst: a warning pertinent to the inclusion gas analysis with thermal opening of inclusions. (A.K.)

PEARSON, M.F., CLARK, K.F. and PORTER, E.W., 1988, Mineralogy, fluid characteristics, and silver distribution at Real de Angeles, Zacatecas, Mexico: Econ. Geol., v. 83, p. 1737-1759. First author at Chen-Northern Inc., P.O. Box 4699, Helena, MT 59604.

The Real de Angeles is a low-grade, bulk tonnage Ag, Pb, Zn, and Cd deposit. The ore minerals occur in thin (1-3 cm wide), discontinuous veinlets related to sedimentary deformation and diagenesis, and to a lesser extent, in fractures and faults of Laramide age. Cavity-filling textures are common. Sulfide mineralization is overlain by a clay alteration assemblage that is overprinted by oxidation. Alteration within the sulfide zone consists of silicification and thin envelopes of propylitic and potassic alteration around the veinlets. Minor occurrences of hornfelsic alteration are observed in the deeper zones of the ore body.

Pyrrhotite, sphalerite, and galena are the most common sulfides, with lesser amounts of arsenopyrite and pyrite. Ag occurs primarily as a solid solution in galena of up to 0.77 wt %. Major gangue minerals include adularia, quartz, fluorite, and calcite. Although adularia is the most abundant, quartz and fluorite accompany ore deposition, and calcite is both pre- and postore.

Analysis of fluid inclusions in adularia, quartz, fluorite, and calcite indicates ore and gangue precipitation from hydrothermal solutions of 1.4 to 21.0 eq wt % NaCl. Quartz and fluorite fluid inclusion Th indicate a Tt of ~290°C.

Sulfur isotope variations are from -4 to -9 per mil $\delta^{34}S$ for sphalerite, pyrrhotite, and galena. A mixing model is proposed of ~60% sedimentary sulfur with 40% magmatic sulfur in the hydrothermal fluid. Comparison of T calculated from sulfur isotope pairs and T formation from fluid inclusions suggests isotopic disequilibrium during ore formation. This is common in sediment-hosted deposits where there is a mixing of sedimentary and magmatic sulfur.

Ore-stage base metal deposition occurred under reducing conditions within the pyrrhotite stability field, although the fO_2-pH conditions of the fluid fluctuated both before and after the ore stage. Sulfur was transported as H_2S. T of formation and salinity, textures of ore and gangue minerals, and hydrothermal alteration indicate an epithermal to mesothermal, fissure vein-stockwork deposit. (From the authors' abstract by E.R.)

PELTONEN, P.T., CRESSWELL, R.G. and RUCKLIDGE, J.C., 1988, Minor gases in zeolites (abst.): GAC/MAC Program with Abstracts, v.13, p.A96.

PENG, Shenglin, 1988, The experimental results of Pb and Zn partitioning between fluid and melt, and their application to the research on mineralization: Acta Geol. Sinica, v. 62, no. 4, p. 352-360 (in Chinese; English abstract). Author at Dept. Geol., South-Central Univ. Tech., Changsha.

Three linear equations between D((V/L)/Me) and $[m_{NaCl}]$, i.e. ln D((V/L)/Pb) = 1.15 ln $[m_{NaCl}$ + 0.85 (0.1 M $\leq$ [m $_{NaCl}$] $\leq$ 0.7 M), ln D((V/L/Pb) = 0.7153 ln $[m_{NaCl}]$ + 0.68 (0.7 M < $[m_{NaCl}]$ $\leq$ 6M) and ln D((V/L)/Zn) = 0.46 $[m_{NaCl}]$ - 0.675 (0.1 M $\leq$ $[m_{NaCl}]$ $\leq$ 6 M, and the relationship of D((V/L)/Me) versus F/Cl or K/Na mole ratios have been established by the experiments of the partitioning of Pb and Zn between granitic silicate melt and aqueous fluid. These results have been used to quantitatively study some essential problems, such as the Pb-Zn mineralization possibility and scale in the system of granitic magma and hydrothermal fluid, and the influence of the relative contents of alkali and volatiles on the Pb-Zn mineralization in the same system.

The calculation and analysis show that in the system of granitic melt and hydrothermal fluids, the relative contents of Cl, F, H_2O, K and Na may all affect the partitioning of Pb and Zn between melt and fluid. The increase of Cl (Na) fractions in the fluid is favorable for fluid extraction of Pb and Zn from the granitic melt, but the increase of F (K) may more or less hinder this extraction. An appropriate content of water in the melt may contribute to the increase of concentrations and contents of Pb and Zn in the fluid.

Fluids released during granitic magmatic crystallization or magma-boiling due to P reduction possess a mineralization potentiality, and those released during the early-middle stage have a greater potentiality. 4 km^3 of granitic magma can provide the fluid with such an amount of metal material [that it is] capable of forming a medium-sized Pb-Zn deposit. If a larger volume of magma exists or the participation of metal material from other sources (such as strata) occurs, a larger Pb-Zn deposit may be formed.

The best potential region for exploration for large Pb-Zn deposits in Henan is the area containing small hypabyssal, relatively Cl(Na)-rich calc-alkaline rock bodies of Diwa (geodepression) stage and late Palaeozoic platform carbonate strata. (Author's abstract)

PERKINS, D., 1988, Geothermometry and geobarometry: Not as precise as we want and unlikely to get any better (abst.): Terra cognita, v. 8, p. 265. Author at Dept. Geol., Univ. North Dakota, USA.

During the last 10 years there has been a proliferation of papers dealing with thermometry and barometry of high-grade rocks. Some of these papers have presented "new and improved" calibrations of thermometers/barometers; others have reported P's and T's for a variety of metamorphic terranes. The goal has been to calibrate thermometers and barometers that would yield accurate and precise peak metamorphic P's and T's. After an early sprint towards this goal, things have slowed down. There have been few major advances in recent years.

The reasons for the slow-down are (1) measured thermodynamic data have been found to be too uncertain for direct calculation of thermometers/barometers; (2) experimental studies that apply over wide composition ranges are time consuming and often difficult to evaluate; (3) some popular reactions used for thermometry/barometry are very sensitive to small analytical errors; (4) activity-composition relationships for any important mineral are poorly understood; (5) many minerals can be shown to have poor memories of peak P and T.

Thermobarometry using garnet(Gt)-clinopyroxene(Cpx)-plagioclase(Pl)-quartz(Q) provides a depressing case in point. Numerous thermometers based on Fe-Mg exchange between Gt and Cpx have been proposed; none have precisions better than 50° and accuracies are unknown. Recent high-quality experiments have not improved the situation, and the complexities of Cpx solutions are still poorly understood. Barometry based upon Gt-Pcx-Pl-Q is equally problematic. Best results suggest this barometer is good to ±2 kbars, but is usually reset during retrogression. Similar problems exist with other often used thermometers/barometers such as Gt-Bi and Gt-Si-Pl-Q.

More calibrations of the same reactions will not help; nor will secondary calibrations of other reactions. Random applications to new terranes will not yield new information. More high-quality experimental studies need to be conducted and careful analysis of applications to natural assemblages must be made. (Author's abstract)

PERRY, S.J., 1988, Fluid inclusions and stable isotope study of a mesothermal gold deposit, Boryeon mine, Republic of Korea: MS thesis, Univ. Missouri, Columbia, MO, USA, 86 pp.

PERSIKOV, E.S. and ZHARIKOV, V.A., 1988, The effect of volatiles on the properties of magmatic melts (abst.): Terra cognita, v. 8, p. 73. Authors at Inst. Exper. Min., USSR Acad. Sci., 142432 Chernogolovka, Moscow District, USSR.

The experimental study was carried out on the effect of volatiles (water, carbon dioxide, F, Cl, Ar, hydrogen) on the rheological properties of magmatic melts.

Volatile solubilities were found to form the following series: water>F>hydrogen [sic] carbon dioxide>Cl>Ar. New peculiarities of hydrogen interaction with magmatic melts were discovered. Hydrogen diffusion in magmatic melts is stationary at η >100 poises. At lower η values, hydrogen diffusion in magmatic melts is followed by thermo-capillary convection. At hydrogen P = 5 kb, Ab melting T decreased by 80 ± 10°C. Hydrogen is shown to be a typical representative of transmagmatic fluids. (From the authors' abstract)

PETER, J.M. and SCOTT, S.D., 1988, Mineralogy, composition, and fluid-inclusion microthermometry of sea floor hydrothermal deposits in the Southern Trough of Guaymas Basin, Gulf of California: Canadian Mineral., v. 26, p. 567-587. Authors at Marine Geol. Res. Group, Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

Numerous hydrothermal spires and mounds composed of carbonates, sulfates, silicates, metal (Fe, Zn, Cu, Fe, Pb) sulfides and iron oxides occur at 2000 m water depth in the sediment-filled Southern Trough of Guaymas Basin, Gulf of California. Predominant minerals include calcite, barite, amorphous silica, stevensite, pyrrhotite and marcasite. Major components (>1%) from bulk chemical analyses are Fe, Si, Ca, Ba, CO_2, S and SO_3 (and, for some samples, Pb, Zn, Al, Na and Mg). The Guaymas hydrothermal deposits therefore are fundamentally different from sulfide-rich deposits at sediment-free spreading axes. Microthermometric measurements of aqueous, two-phase inclusions in calcite from chimneys indicate Tt from ~150 to 315°C, and salinities of 3.7 to 8.1 (mean 5.4) eq. wt.% NaCl. Tt are in good agreement with T of venting fluids measured in situ by thermocouple probe. Fluid-inclusion salinities cannot be reconciled with salinities measured from presently venting hydrothermal fluid and suggest that there are temporal variations in the chemistry of the vent fluid. Differences in salinity and Th for P and S inclusions of individual chimneys require that there has been mixing of hot hydrothermal fluid and cold ambient sea water within chimneys and spires. Mineral assemblages and compositions of individual minerals can best be explained by mixing of end-member hydrothermal fluid with sea water. Most minerals are precipitated at the vent site largely in response to decreasing T induced by mixing with sea water. (Authors' abstract)

See next item also. (E.R.)

PETER, J., SCOTT, S.D., SHANKS, W.C., III and WOODRUFF, L.G., 1986, Geochemical, mineralogical, fluid inclusion, and stable isotope studies of hydrothermal vent precipitates, Guaymas Basin, Gulf of California, in The Genesis of Stratiform Sediment-Hosted Lead and Zinc Deposits: Conf. Proc., eds. R.J.W. Turner and M.T. Einaudi, Stanford Univ. Pubs., Geol. Sci., v. 20, p. 151-155.

Full paper for abstracts in Fluid Inclusion Research, v. 19, p. 334, and v. 20, p. 309-310. (E.R.)

PETERS, M., ANDERSON, A.T. Jr., and SCHWINDINGER, K.R., 1988, Dunite cumulates from Mauna Loa, Hawaii (abst.): EOS, v.69, p.524. First author at Dept. of Geophys. Sci., Univ. of Chicago, Chicago, IL 60637.

Dunites as compared with other ultramafic nodules from Damon's Cone on the southwest rift of Mauna Loa have more magnesian olivines (Fo 85-86), chrome-rich chromites, greater deformation, and generally less interstitial glass. Interstitial glass and glass inclusions in various minerals have similar compositions and are similar to average historic Mauna Loa tholeiite. The similar glass and partly overlapping chromite compositions and the similar inferred deformational stresses point to a close genetic relationship between the deformed dunites and the less deformed, other peridotites: both are concluded to have formed in a subsiding cumulate mush within the upper few km of Mauna Loa. (From the authors' abstract)

PETERS, S.G., 1987, Geology, fluid characteristics, lode controls and oreshoot growth in mesothermal gold-quartz veins, northeastern Queensland: PhD dissertation, James Cook Univ., Townsville, Queensland.

See next item. (E.R.)

PETERS, S.G., 1988, Ore shoot growth in mesothermal gold-quartz vein deposits (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 626. Author at Western Mining Corp. Ltd., P.O. Box 401, Charters Towers, Qld. 4820.

Mineralizing fluids in these shear zones range between 3 and 10 wt. % NaCl eq. with $\delta^{18}O$ values of about 5 to 10 per mil. Fluids are locally CO_2-bearing with formation T between 220 and 350°C. Fluid source is either of deep magmatic or metamorphic origin and can rarely be correlated directly with nearby plutonism. (From the author's abstract)

PETERS, Tj., 1987, Hydrothermal alteration of a Variscian granite, magmatic autometasomatism and fault related vein metasomatism, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 577-590. Author at Min.-Petr. Inst., Univ. Berne, Baltzerstrasse 1, 3012 Bern, Switzerland.

Two types of hydrothermal alteration can be recognized in a biotite granite of Variscan age in northern Switzerland. The first is related to the intrusion of the granite and lead to the replacement of K-spar and biotite by muscovite, of plagioclase by sericite and calcite and to a chloritization of biotite. This process affected the granite as a whole. Mass transfer calculations using analyzed mineral compositions indicated locally mass balanced reactions without transport beyond neighboring grains. Using the H_2O and CO_2 (from C?) already present in the granitic melt, this alteration process is an autometasomatism during cooling leading to sericitization/chloritization taking place at 350°C by a fluid with 6.5 wt.[%]eq. NaCl. The second process, the main hydrothermal alteration is connected with young Palaeozoic faulting and locally anomalous heat flow. This process has lead to a vein parallel zonation shown by clay minerals. During this stage of alteration process the granite was depleted in the major elements Si and Na and in the trace elements Sr, Ba and U. This depletion lead to an increased porosity. Fluids evolved from 7 wt. % NaCl eq. at T 350°C down to 0.1 wt. % NaCl at T 90°C. The composition of this fluid was calculated, assuming equilibrium with the fissure minerals quartz, albite, K-spar and illite. Because the low water/rock ratio indicated by stable isotope data, a model of repeated water recycling between the fissure and the rock is proposed. (Author's abstract)

PETERS, Tj., MATTER, A., BLÄSI, H.R. and GAUTSCHI, A., 1987, The Böttstein exploration borehole. Geology. 207 pages with an extensive appendix: "Fluid Inclusions" by Stalder, H.A., p. 140-147, appendix 7.22 (in German): Geologische Berichte der (Schweizerischen) Landeshydrologie und -Geologie. [Geological Reports of the National Survey of Hydrology and Geology (from Switzerland)], 1987, no. 1, (in German).

PETERSEN, E.U. and MAHIN, R.A., 1988, Characteristics and timing of rare metal (Ga, Ge) hydrothermal systems: Apex Mine, Tutsagubet district, SW Utah (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A142. Authors at Dept. Geol. & Geophys., The Univ. Utah, Salt Lake City, UT 84112.

Gallium, germanium, copper and Pb mineralization occur in breccia pipes developed in the Pennsylvanian Callville Fm. of the Beaver Dam Mountains, southwestern Utah. Mineralization consists of early quartz I-illite-alunite-family minerals-minor sulfides, followed by high-T quartz II-goyazite/svanbergite-copper and Pb sulfides, and overprinting by jarosite-family minerals and iron oxides in the core of the pipe and numerous base metal carbonates at the periphery. Gallium resides in chalcopyrite (0-1300 ppm), crystalline jarosite (0-1,010 ppm) and in beudanite (60,200 ppm). Germanium (0-5,300 ppm) is irregularly distributed in a complex mixture of iron oxides.

Main stage hydrothermal fluids (quartz II) were hot (200-400°C), dilute (<2 wt. % NaCl eq.) aqueous solutions which boiled locally. No CO_2 was detected. P fluctuated between hydrostatic and lithostatic at very shallow depths. Estimated T from sulfur isotope data on galena ($\delta^{34}S$(ga) = -2.5 to -0.4%) and pyrite ($\delta^{34}S$(py) = +0.9 to +3.6%) are in the range indicated by the FI data.

The oxygen isotopic composition of main stage fluids, calculated from $\delta^{18}O$(quartz II) (+25.3 to +28.7% , SMOW) for the T interval of 200 to 300°C, range from +14 to +22% . These heavy fluids could be metamorphic waters or highly exchanged (W/R <0.1) meteoric or magmatic waters.

The strontium in hydrothermal Sr-bearing sulphates ($^{87}Sr/^{86}Sr$ >0.7105) is more radiogenic than that in the carbonate host rocks (0.7085) and carbonate rocks in general (0.7067-0.7090), but less radiogenic than that in the Cambrian Bright Angel (Cba) Shale (0.753) or the Precambrian basement (0.722) indicating a near-basement or basement source for some of the strontium. Secondary Sr-bearing sulphates (0.7085) contain strontium of local origin.

K/Ar dating of hydrothermal muscovite yielded an age of 200 ± 7 m.y. for main stage mineralization. K/Ar measurements on jarosite gave mid- to late Miocene ages corresponding closely with the timing of Basin and Range extension in southwestern Utah. (Continued)

We infer that meteoric waters circulated extensively through the thick (2.7 km) carbonate cover and interacted with the Cba shale and/or basement rocks leaching rare and base metals as well as some strontium from these source rocks. (Authors' abstract)

PETIT, C.J., HWANG, M.-H. and LIN, J.-L., 1988, Thermal diffusion of dilut aqueous NH_4Cl, Me_4NCl, Et_4NCl, n-Pr_4NCl, and n-Bu_4NCl solutions at 25°C: J. Solution Chem., v. 17, no. 5, p. 1-13.

PETRICHENKO, O.I., 1988, Physico-chemical conditions of sedimentation in ancient salt basins: Kiev, Naukova Dumka Pub. House, 126 pp. (in Russian). ISBN 5-12-000199-8; 480 copies printed; price 2 roubles, 20 kopecks.

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(Translation by T.M. Sushchevskaya)

PETROV, P.P., 1988, Inclusions with mineral-forming solutions in quartz of the antimonite Mareshitsa ore manifestation (Eastern Rhodopes): Comptes-rendus de l'ABS, 1988, no. 2, p. 87-88 (in English).

The ore manifestations occur 3 km southeast of the village of Senoklas, district of Haskovo (South Bulgaria). A vein cuts through the sediments of the Lower Paleogene molassa formation. Quartz and stibnite are the main minerals. Three kinds of quartz are distinguished: clear, milky and chalcedony. The stibnite mineralization associates only with the clear quartz. Doubly polished platelets of quartz and quartz-stibnite aggregates are examined. Gas-liquid and liquid inclusions are observed as well as a solid phase inside the inclusions which resembles a stibnite crystal. The Th of fluid inclusions containing 8-15% of gas is relatively constant and is about 150-130°C. It is believed that the quartz-stibnite mineralization studied is a low-T formation. (Abstract by S. Aslanjan).

PETROVSKII, V.A., 1983, Crystal growth in heterogeneous solutions: N.P. Yushkin and A.M. Askhabov, eds., Nauka Press, Leningrad (in Russian).

Of pertinence in the problems of trapping of fluid inclusions from heterogeneous fluids. (E.R.)

PETROVSKY, V.A., KUCHER, M.I., LYUTIN, V.I., SILAEV, V.I., BORODIN, V.L., DRONOV, V.V., FILLIPPOV, V.N. and PETRAKOV, V.P., 1988, Manifestation of the inhomogeneity of the mineral-forming medium in the structure and properties of synthetic crystals of calcite, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 43-48 (in Russian).

PETRUCCI, E. and CAPRARELLI, G., 1988, Fluid inclusions in the Larderello (Toscana) geothermal field: New data from Monteverdi 2 and San Giovanni 1-bis wells (abst.): Soc. Ital. Mineral. Petrol. "SIMP Notizie," no. 7, p. 91.

Quartz crystals from wells in the Monteverdi Marittimo area (western edge of the Larderello geothermal field) contain P, PS and S biphase inclusions, that may be either L-rich or V-rich, and triphase inclusions (L + V + S - possibly halite). Calculated salinities range from 1 to 12% wt. NaCl eq. [presumably for biphase inclusions only - PL], and Th vary from 262° to 366°C. (Partial translation by P. Lattanzi)

PHILLIPS, G.N., KLEMD, R. and ROBERTSON, N.S., 1988, Summary of some fluid inclusion data from the Witwatersrand Basin and surrounding granitoids: Geol. Soc. India Memoir 11, p. 59-65. First author at Box 228, Cottesloe, 6011, WA, Australia.

Fluid inclusions in altered granitoids surrounding the Witwatersrand Basin, and in auriferous quartz veins within the Witwatersrand succession, include both saline-aqueous, and low salinity, CO_2-rich inclusions. Th range from 150 to 200°C, and Tt up to 350°C have been inferred. These inclusions suggest a dynamic post-depositional history for the Witwatersrand Basin that probably includes diagenetic and metamorphic fluid activity.

There is a need for systematic fluid inclusion studies covering the different mines, structural settings and vein generations within the Witwatersrand Basin. The numerous quartz veins intimately associated wit Au reefs would be very suitable for such studies. (Authors' abstract)

PIKOVSKIY, Yu.I., KARPOV, G.A. and OGLOBLINA, A.I., 1987, Polycyclic aromatic hydrocarbons in products of the Uzon hydrothermal system as related to the origin of Uzon oil (Kamchatka): Geokhimiya, no. 6, p. 869-876 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 1, p. 103-110). Authors at Moscow Univ., Inst. Volcanol., Far Eastern Sci. Center, USSR Acad. Sci., Petropavlovsk-Kamchatskiy, USSR.

Data on polycyclic aromatic hydrocarbons (PAH) in oils, hydrocarbon inclusions, hot springs, subsoils and subsoil waters of the thermal fields and soils of the Uzon caldera on Kamchatka are presented. The most abundant and diverse PAHs are associated with oils and chloride hot springs that are confined to faults and thermal anomalies. In terms of PAH distribution, the Kamchatka oils are intermediate between the bituminous material in hydrothermal products and the oil of the oil fields. The hydrocarbons in the Uzon caldera are genetically related to the material of the hydrothermal system. (Authors' abstract)

PINEAU, F., 1988, Characterization and isotopic composition of fluid inclusions in peridotite nodules (abst.): Chem. Geol., v. 70, p. 55. Author at Lab. Géochimie des Isotopes Stable, Dept. Sci. Terre, Univ. Paris VII & Inst. Phys. du globe, 2 place Jussieu, 75 251 Paris Cedex 05, France.

Carbon has been extracted from ultramafic and mafic nodules from various environments (Hualalai volcano, Hawaii, and various volcanic localities of the NW Cordillera of North America). Extraction procedures include step-heating oxidation or pyrolysis, with or without melting flux and 100% H_3PO_4 acid attack. These techniques allow us to define two major carbon sources.

The first one constitute 30 to 95% of the total carbon extracted (ILC carbon). It is isotopically light: 20 to 500 ppm C with δ^{13}C between -24 to -28 permil/PDB. Its major peak is obtained around 400°C but it can be traced up to 1450°C. It is associated to late condensation products originating from interaction between fluids and surfaces.

Another peak, obtained between 1200 and 1450°C, corresponds to the appearance of fluid inclusions (FI): 0 to 110 ppm C with δ^{13}C between -2 and -10 permil/PDB. Small amounts of ILC (1 to 25 ppm) can be extracted above the FI peak. Pyroxenite or gabbroic veinlets seem to be depleted in carbon relative to their host peridotite. The variations observed point out to the fact that CO_2 introduced in the nodules prior to eruption is fractionated from magmas at various depths (40 to 5 km) during their ascent. (Author's abstract)

PINEAU, F. and JAVOY, M., 1988, Carbon isotopes in peridotite nodules (abst.): EOS, v.69, p.502. First author at Laboratoire de Géochimie des Isotopes Stables, UA CNRS 196, Univ. Paris VII, FRANCE.

C has been extracted from peridotite nodules from hot spot and subduction zone environments with mineralogy from spinel and amphibole lherzolithes to harzburgites, wherlites, dunites, and various pyroxenites. Extraction procedures include step-heating oxidation or pyrolysis, with or without melting flux, and 100% H_3PO_4 acid attacks.

In all cases two main types of C have been extracted. In step heating experiments one component is extracted from low (≈300°C) up to very high (≈1400°C) T with a peak usually around 400°C. This component with low (-25 to -32°‰.)∂^{13}C is tentatively associated to the C deposits described by Mathez, 1987 [this volume] as late condensation products originating from the interaction with the host lava (LTCC component) and identified as organic compounds and intercalation compounds of graphite. A large part of these compounds can be extracted by phosphoric acid attack, mainly as incondensible molecules and very little CO_2.(continued)

The CO_2 from fluid inclusions (Fl component) is always extracted at high (1200°C) to very high (1450°C) T. The use of a flux produces a burst of these fluid inclusions around 1300°C. Their $\partial^{13}C$'s are systematically high (-2 to -10 ‰), irrespective of the geodynamic setting. On the contrary the pyroxenite veinlets are systematically depleted in C relative to their host peridotite, pointing to the fact that isotopic fractionation is produced mainly during the feeding of the nodules in C by incoming magma at various depths during the ascent. (From authors' abstract)

PITMAN, J.K. and BURRUSS, R.C., 1988, Diagenetic evolution of deep hydrocarbon-bearing rocks in the Ordovician Simpson Group, Anadarko Basin, Oklahoma; evidence from mineralogic, stable isotope, and fluid inclusion studies: U.S. Geol. Survey Circular 1025, p. 48.

PLIMER, I.R., ANDREW, A.S., JENKINS, R. and LOTTERMOSER, B.G., 1988, The geology and geochemistry of the Lihir gold deposit, Papua New Guinea (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 139-143. First author at Dept. Geol., Univ. Newcastle, N.S.W.

Two principal types of fluid inclusions occur. The first is supersaline and is characterized by up to 15 different dm chlorides, sulphates and sulphides. Fourier transform infrared and mass spectrometry demonstrated the presence of gaseous CO_2, H_2S, CH_4 and higher hydrocarbons in these inclusions. The second type of inclusions have variable but high gas:liquid ratios and contain gaseous CO_2, H_2S and CH_4. The fluid inclusions demonstrate evidence of boiling from the deepest collected sample (750 m below the caldera floor) to the surface. The absence of wairakite, rarity of epidote, presence of carbonate, abundance of adularia in the potassic zone and the ubiquitous presence of CO_2-rich fluid inclusions is commensurate with a CO_2-rich magmatic fluid derived from alkaline igneous activity. (From the authors' abstract)

PLUMLEE, G.S., 1988, Chemical modeling of ore and gangue deposition in the Creede, Colorado, epithermal system (extended abst.): U.S. Geol. Survey Circular 1035, p. 55-57.

A comprehensive and coordinated study of the geology, geochemistry, mineralogy, and fluid inclusions in the numerous veins in this district. Full paper forthcoming. (E.R.)

PLUMMER, L.N. and PARKHURST, D.L., 1988, Geochemical calculations in brines: Application of the Pitzer model to PHREEQUE (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). First author at U.S. Geol. Survey, Reston, VA.

PHRQPITZ is a FORTRAN 77 modification of the computer code PHREEQE that is capable of making geochemical calculations in brines and other electrolyte solutions to high concentrations using the Pitzer virial-coefficient approach for activity-coefficient corrections. Reaction-modeling capabilities include calculation of (1) aqueous speciation and mineral saturation indices, (2) mineral solubilities, (3) mixing or titration of aqueous solutions, (4) irreversible reactions, and (5) reaction paths. The computed results for each aqueous solution include the osmotic coefficient, activity of water, mineral-saturation indices, mean-activity coefficients, total-activity coefficients, and scale-dependent values of pH, individual-ion activities, and individual-ion-activity coefficients. The program data base of Pitzer interaction parameters includes the partially validated data base of Harvie, Moller and Weare (1984) at 25°C for the system $Na\text{-}K\text{-}Mg\text{-}Ca\text{-}H\text{-}Cl\text{-}SO_4\text{-}OH\text{-}HCO_3\text{-}CO_2\text{-}H_2O$. The data base also includes largely untested literature data for Fe(II), Mn(II), Sr, Ba, Li, and Br, with provision for calculations at T other than 25°C. The need to maintain an internally consistent data base of interaction parameters and equilibrium constants is emphasized through an example of the calculated solubility of nahcolite in Na_2CO_3 solutions. The choice of activity coefficient scale has particular significance to thermodynamic calculations in brines if the measured pH is introduced. It is important to recognize the limitations and uncertainties of thermodynamic calculations in brines. (Authors' abstract)

PLYASUNOV, A.V., BELONOZHKO, A.B., IVANOV, I.P. and KHODAKOVSKIY, I.L., 1988, Solubility of zinc oxide in alkaline solutions at 200-350°C undersaturated steam pressure: Geokhimiya, 1988, no. 3, p. 409-417 (in Russian; translated in Geochem. Int'l., v. 25, no. 10, p. 77-85).

POGUE, Randall and ATKINSON, Gordon, 1988, Solution thermodynamics of first-row transition elements. 1. Apparent molal volumes of aqueous $NiCl_2$, $Ni(ClO_4)_2$, $CuCl_2$, and $Cu(ClO_4)_2$ from 15 to 55°C: J. Chem. Eng. Data, v. 33, p. 370-376.

POHL, D.C. and BEATY, D.W., 1988, A telluride geothermometer assemblage from a new manto type Au-Ag deposit, Buckeye Gulch, Tennessee Pass area, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A38. First author at American Museum of Natural History, New York, NY 10024.

In 1984, a new, high-grade Au-Ag zone was discovered in outcrop and in several deep drill holes in Buckeye Gulch in the Tennessee Pass area, about 8 km north of Leadville. The mineralization occurs as a 0.6 m thick massive sulfide manto in the Mississippian Leadville Dolomite and shows a great diversity of telluride minerals. The bulk of precious metals is evidently present as tellurides.

The tellurides in the Buckeye Gulch prospect occur as minute 1-10 μm ovoid inclusions in massive, coarsely crystalline pyrite with occasional inclusions to 150 μm. The inclusions occur as isolated blebs, in trains and as arrays in the cores of pyrite which has been mildly brecciated. Based on textural evidence the tellurides either predate or are coeval with the pyrite mineralization. Occasionally, traces of tellurides are found in fractures offsetting inclusions. These appear to be remobilized from preexisting tellurides. To date, 11 telluride minerals have been identified including a possibly new Ag telluride phase as well as very minor, chalcopyrite, covellite and tetrahedrite. The most common tellurides are hessite (Ag_2Te), stuetzite ($Ag_{5-x}Te_3$), and altaite (PbTe), with subordinate petzite (Ag_3AuTe_2), sylvanite ($AuAgTe_4$), Ag-bearing kostovite ($AuCuTe_4$), rickardite ($Cu_{4-x}Te_2$), weissite ($Cu_{2-x}Te$), coloradoite (HgTe), native tellurium (Te). The unknown phase appears to have a composition close to Ag_2Te_5. Most inclusions are single phase but in polyphase inclusions the phases appear to be in sharp equilibrium contact, except for obvious replacement textures of chalcopyrite by rickardite and weissite.

The polyphase inclusion assemblage hessite-sylvanite-native tellurium-kostovite meets the criteria of excess Ag and Te for the "Ag in sylvanite" geothermometer. Microprobe measurements of Ag in sylvanite range from 10.6 to 12.5 wt % Ag, indicating T of formation from 325°C down to 250°C. These T are 50-125°C higher than those normally suggested for Au-Ag telluride mineralization but are in good agreement with limited fluid inclusion and oxygen isotope T of vein quartz in Buckeye Gulch. (Authors' abstract)

POLLACK, H.N. and CERCONE, K.R., 1988, Are anomalous thermal maturities in sedimentary basins due to the low thermal conductivity of carbonaceous deposits? (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A259. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109-1063.

Many studies of ancient sedimentary basins have noted extremely high levels of thermal maturity, using thermal indicators as varied as vitrinite reflectance, sporopollen coloration, fission-track closure and fluid inclusion thermometry. Explanations of these anomalous maturity levels have included thermal events unrelated to basin subsidence and removal of several km of overburden from the basins. We propose that the anomalous maturity of some basins may derive from a much thinner overburden of carbonaeous strata, occurring near (or eroded from) the top of the stratigraphic sequence.

Although studies of thermal conductivity in carbonaceous material are few, the data indicate that coal beds and rocks which contain dispersed coaly material have thermal conductivities lower by a factor of five to ten compared to more typical values for sediments. As a result, geothermal gradients across carbonaceous units can range from 60° to 120°C/km in basins with ordinary heat flow. Such elevated gradients high in the stratigraphic section can cause T to rise in all underlying strata without requiring any change in basement heat flow or unusual depth of burial. We postulate that this "thermal-blanketing" has affected many coal-bearing regions, including those sedimentary basins in Europe and North America which have served as paradigms for organic maturation and ore genesis. (Authors' abstract)

POLYA, D.A., 1988, Total masses of hydrothermally transported components in the ore veins and in the associated alteration halo at Panasqueira, Portugal: A comparison (abst.): EOS, v.69, p.468. Author at Geo. Dept., Univ. of Manchester, Manchester, M13 9PL, UK.

At the Panasqueira W-Cu(Ag)-Sn deposit in Portugal, the ore forming elements (OFE's) are concentrated into a network of quartz veins that occupy a volume of about 0.005 km^3. The orebody is mantled by a much larger volume (5-15 km^3) of variably hydrothermally altered Beira Schists, in which the OFE's are dispersed in much lower concentrations than in the orebody itself.

The W, Sn, Cu, Zn, and As concentrated in the orebody represent only 33%, 10%, 7%, 3%, and 2% respectively of the total masses of these elements hydrothermally introduced to in and around the Panasqueira deposit.

The orebody is therefore revealed as a quantitatively minor manifestation of a much larger crustal hydrothermal alteration system. The differences in efficiency of concentration of OFE's from the ore forming fluids into the ore veins at Panasqueira possibly reflect the differences in the pressure dependence of wolframite, cassiterite and sulfide solubilities. (From the author's abstract)

POMÂRLEANU, Vasile, 1987, Glass and fluid inclusions in some basic volcanics in the Calimani Mountains: D.S. Inst. Geol. Geofiz., v. 72-73, no. 1 (1985; 1986), p. 339-344 (in English). Author at Inst. Geol. si Geofiz., str. Caransebes nr. 1, R 79678, Bucuresti 32.

Four types of glass and fluid inclusions were found in the olivine, pyroxene and plagioclase phenocrysts in the basaltic andesites on the Haita Valley, Delut (Lomas Valley) and Ploptis (Sarmas). The study of these inclusions indicates that basaltic andesites derived from lavas with a low and moderate viscosity rich in [incompatible elements]. Vesiculation of the melt which had generated these rocks began at depths corresponding to the upper mantle. (Author's abstract)

Silicate melt, CO_2, and aqueous with dm NaCl are described. (E.R.)

POMÂRLEANU, Vasile, 1988, Glass and fluid inclusions in some basic volcanics in the Calimani mountains: D.S. Inst. Geol. Geofiz, v. 72-73/1, p. 339-344 (1985-7; pub. 1988) (in English). Author at Inst. Geol. si Geofizica. Str. Caransebes nr. 1, R 79678 Bucuresti, 32.

Four types of glass and fluid inclusions were found in the olivine, pyroxene and plagioclase phenocrysts in the basaltic andesites in the Haita Valley, Delut (Lomas Valley) and Ploptis (Sarmas). The study of these inclusions indicates that basaltic andesites derived from lavas with a low and moderate viscosity rich in immiscible [incompatible?] components. The vesiculation of the melting[sic] which had generated these rocks began at depths corresponding to the upper mantle. (Author's abstract)

POMǍRLEANU, Vasile and GRǍDINARU, Eugen, 1988, Fluid inclusion and genetic significance of quartz veins from Alba beds (Upper Triassic), Cartal Hill, North Dobrogea: Analele Univ. Bucuresti, v. 37, p. 9-16 (in English). First author at Inst. Geol. & Geophys., Caransebes 1, R 79678 Bucharest 32.

The quartz crystals filling a vein which crosscut the Alba beds in the area of the Cartal Hill are studied as concerns their crystallography, fluid inclusions and geothermometry. The obtained data and the geologic setting testify that the quartz veins were genetically related to the thrusting processes of the Niculitel Unit, these ones triggering sufficiently high friction heat to generate silica-bearing epigenetical solutions under hydrothermal conditions. (Authors' abstract)

POMÂRLEANU, Vasile and ÎNTORSUREANU, Ion, 1985, Salinity of fluid inclusions of the porphyry copper ore deposits and their significance in geobarometry and prospecting (the Lapusnicu Mare ore deposit - Banat): D.S. Inst. Geol. Geofiz., v. 70-71/2 (1983; 1984), p. 83-95 (in English). Authors at Inst. Geol. si Geofiz., str. Caransebes nr. 1, R 79678, Bucuresti 32.

According to the study of fluid inclusions there were determined the main thermodynamic factors of ore forming fluids, such as: T (200-500°C), P (120-400 bars), salinity (2-5% NaCl), as well as some characteristics of boiling mechanisms of solutions in porphyry systems. There were pointed out as well some relationships between the distribution of salinity and the Cu content, in a horizontal and vertical profile through the ore. The study discusses as well the advantages of data concerning salinity in inclusions from prospection, together with other prospecting methods. (Authors' abstract)

POMÂRLEANU, Vasile, IOANID, Ghiocel and RUSCIOR, Radu, 1986, New aspects of fluid-inclusion decrepitation and its implication in prospecting: Geologie, v. 30, p. 39-42 (in Romanian; English abstract).

The decrepitograms of any mineral obtained by recorder directly connected to a decrepitation device and to a tape recorder point to identical values of the beginning and maximum intensity of decrepitation and of corresponding T intervals. These values, represented on the studied area, are used to delimit the decrepitometric anomalies surrounding a blind ore body. (Authors' abstract)

POMÂRLEANU, Vasile, LAZǍR, Constantin and ÎNTORSUREANU, Ion, 1988, Fluid inclusions in the mineralizations from the Valea Lita - Baisoara - Cacova Ierii area (Apuseni Mountains): D.S. Inst. Geol. Geofiz, v. 72-73/2, p. 127-143 (1985-6; pub. 1988) (in English). First author at Inst. Geol. si

Geofizica, str. Caransebes 1, R 79678, Bucuresti 32.

Fluid inclusions in some skarn and hydrothermal minerals genetically related to the banatitic rocks from the Valea Lita - Baisoara - Cacova Ierii area as well as the fluid inclusions from the quartz phenocryts occurring in banatite rocks and inclusions from some recrystallized metamorphic rocks have been studied. There is a correspondence between the known ore deposits and the occurrences of the ore-forming solutions of the highest salinity (30-50 wt% NaCl). The latter may be followed from Valea Lita through Baisoara and Masca to the Vadu Valley. Based on the study of fluid inclusions and on microscopic investigations, the mineralogenetic stages, the mineral assemblages, the peculiarities of ore-forming solutions, the decrepitation and/or Th and the sequence of the main minerals have been determined. Using the mentioned results a model of the mineralogenetical processes developed in the investigated area has been sketched. (Authors' abstract)

POMÂRLEANU, Vasile, MIRAUTA, Elena, NEAGU, Eleonora, 1988, Contributions on the Bogza mineralizations (northern Dobrogea): D.S. Inst. Geol. Geofiz, v. 72-73/1, p. 145-155 (1985-7; pub. 1988) (in French; English abstract). Author at Inst. Geol. si Geofizica. str. Caransebes 1, R 79678 Bucuresti, 32.

Cu and barite mineralizations occur both in Early Werfenian sandstones and conglomerates and Spathian limestones as well. The study of fluid inclusions shows that both types are hydrothermal mineralizations. Gradually they passed from epi- to mesothermal type and deposited from 140° to 280°C. (Authors' abstract)

POMÂRLEANU, Vasile and NEAGU, Eleonora, 1988, Fluid inclusions in the mineralizations at Tibles: Implications in mineralogenesis: D.S. Inst. Geol. Geofiz, v. 72-73/2, p. 157-167 (1985-6; pub. 1988) (in English). First author at Inst. Geol. si Geofizica, str. Caransebes 1, R 79678, Bucuresti 32.

The fluid inclusions from the vein mineralizations of the central-northwestern group as well as those in some secondary minerals of the magnesian skarns have been studied. Biphase and triphase fluid inclusions have been found. The thermal regime of solutions ranged between 400 and 230°C for the base metal mineralization and between 260-150°C for some late assemblages. The CO_2 content of solutions expressed as the CO_2/H_2O molar ratio indicates lower values 0.079-0.090 than in the case of some other deposits. The salinity of solutions ranges between 3-16% NaCl for the vein mineralizations. The calcite deposited on fissures in the magnesian skarn minerals is marked by a high salinity, 30-33 wt% NaCl, P of ~120 bars and depth of over 1000 m. (Authors' abstract)

POMÂRLEANU, Vasile and NEGREA, Eugen, 1988, Preliminary data on the distribution of fluid inclusions in the Upper Paleozoic sedimentary rocks from the Lupac region (Resita Zone): D.S. Inst. Geol. Geofiz, v. 72-73/5 (1985; 1986), p. 179-185 (in English). Authors at Inst. Geol. si Geofiz., str. Caransebes nr. 1, R-79678, Bucuresti 32.

Investigations on the detrital components and the fluid inclusions from some sandstones and conglomerates belonging to the Lupac region were carried out. They provided information on the origin of the detrital elements and on the tectonic and hydrothermal effects that influenced them after their consolidation. (Authors' abstract)

POMÂRLEANU, Vasile, RADUT, Marian and NEAGU, Eleonora, 1985, Contribution to the thermodynamic and geochemistry features of hydrothermal solutions based on fluid inclusion at Baia Mare - Suior Area: Geologie, v. 30, p. 102-110 (in Romanian; English abstract). (Continued)

In this paper the authors aimed to present some new data on the types of fluid inclusion, both in vein and wall rocks.

Based on P fluid inclusions, the thermic regime of hydrothermal solutions is determined on the entire area and is ranging from 126° in outcrop zones to more than 400°C in the XV and XVI levels at Baia Sprie.

The data for molar ratio CO_2/H_2O obtained by gas chromatographic method, from main vein (Baia Sprie), show an increase from XVI level (0.002 CO_2/H_2O) to +516 level (0.337 CO_2/H_2O). The higher contents of CO_2 in the upper levels are attributed to the Au-Ag zone and to the adularization process.

The cooling of hydrothermal solutions from 700°C to about 350°C T took place by irreversible adiabatic process and to 126°C by mixing with ground water. (Authors' abstract)

POMÅRLEANU-NEAGU, Eleonora and MÅRZA, Ioan, 1987, The fluid inclusion and the hydrothermal quartz geothermometry from the Afinet breccia pipe at Tarna Mare (Maramures County): Studia Univ. Babes-Bolyai, Geologia-Geographia, v. 32, no. 1, p. 45-51 (in French; English abstract). First author at L'Inst. de recherche, ingénieurie technol., conception & production pour l'industrie anorganique et les metaux non ferreux, Bucarest, 102, rue Biruinte, Romania.

Fluid inclusions and the geothermometry of the hydrothermal quartz in the breach structure at Afinet, Tarna Mare (Maramures County) are presented. Two quartz generations are evidenced, corresponding to two metallogenic stages. Quartz I is characterized by gas-rich inclusions (H_2S) (Th 205-260°C), quite rare essentially-liquid (240-270°C), and S inclusions (130-220°C), the latter marking the crystallizing geothermal range of quartz II. The metallogenic stages, assessed relying on the geometry of quartz (I, II), correspond to the mesothermal range identified by crystallization of pyrite, chalcopyrite (>220°C), sphalerite, galenite, etc. (240-265°C) and to the epithermal one (<220°C) characteristic of the deposition of marcasite-cinnabar paragenesis, especially in the area below 130°C. (Authors' abstract)

PONCE S., B.F. and CLARK, K.F., 1988, The Zacatecas mining district: A Tertiary caldera complex associated with precious and base metal mineralization: Econ. Geol., v. 83, p. 1668-1682. Authors at Dept. Geol. Sci., Univ. Texas at El Paso, El Paso, TX 79968.

Three groups of veins are recognized, varying in ore assemblage and structural position: (1) the most important and extensive is the Ag-(Pb, Zn, Cu, Au) system, occurring in concentric and tangential faults and fractures that cut precaldera rocks; (2) the Au-Ag(Se) system, located in radial fractures that were emplaced in the caldera-fill host rocks; and (3) the F system, subparallel to the other margin of the caldera and also located in caldera-fill lithologies. Ag, the dominant precious metal, occurs mainly as acanthite, Ag sulfantimonides, such as freibergite, and native Ag. Free Au and electrum were identified optically, and aguilarite (Ag_2SeS) was identified for the first time in the district. Pyrite, sphalerite, galena, and chalcopyrite are also present. Gangue minerals are mainly quartz and calcite.

Preliminary fluid inclusion data on samples from the Cantera vein system, which contains precious and base metals, fall in the range 300° to 160°C. The early Tertiary mineralization in the district is epithermal and controlled by volcanotectonic features, modified by erosion, oxidation, and supergene enrichment. (From the authors' abstract by E.R.)

POPIVNYAK, I.V., LEVITSKY, V.V., DEMIN, B.G. and KHRENOV, P.M., 1988, The periodicity of involvement of elements in crystallogenesis as examplified by one of the mineral-forming paleosystems (Northern Buryatia), in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 248-258 (in Russian).

POTY, B. and PAGEL, M., 1988, Fluid inclusions related to uranium deposits: A review: J. Geol. Soc., London, v. 145, p. 157-162. Authors at Centre de Rech. sur la Geol. de l'Uranium & GS CNRS-CREGU, B.P. 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Fluid inclusions have been observed and studied in rocks of most types of uranium deposits, except surficial ones such as calcretes and the roll-type in sandstone. T of formation range up to nearly 400°C but most deposits were formed at more moderate T of 90-250°C. It is evident from the relatively small number of studies, however, that the ore-forming process occurred at deeper levels than previously thought.

The chemistry of the fluids ranges from nearly pure water to very dense brines and CO_2 is a common component. In some cases gas analyses allow determination of fO_2 of the fluid, a key parameter for uranium transport and deposition. (Authors' abstract)

POULSON, S.R. and OHMOTO, Hiroshi, 1988, Devolatilization equilibria in graphite-pyrite-pyrrhotite-bearing pelites, with respect to magma-pelite interaction and dehydration reactions (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 67. Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802, USA.

The proportions of species in a C-O-H-S fluid (with ideal mixing) in equilibrium with graphite, pyrite, and pyrrhotite were calculated for a range of P, T, and $f(O_2)$ using the same method employed by Ohmoto and Kerrick (1977), but using a corrected expression for the pyrite-pyrrhotite equilibrium.

Under typical metamorphic conditions, H_2O, CO_2, CH_4 and H_2S are the principal fluid species, with H_2S becoming the dominant species at elevated T (e.g., T >500°C for P(fluid) = 1 Kb, $X(CO_2) = X(CH_4)$, and T >700°C for P(fluid) = 4 Kb, $X(CO_2) = X(H_2O)$). This provides a mechanism for the selective transfer of sulphur from a graphite-pyrite-pyrrhotite-bearing pelite into an emplaced magmatic body via a fluid phase, without requiring wholesale melting and assimilation of bulk material. Such a process is feasible if a magma is intruded by a stoping mechanism, allowing a significant volume of pelite to be raised to T approaching that of the magma. This has important implications for metallogenesis, as the H_2S-rich fluids produced in this environment may transport ore-forming metals as sulphide complexes.

The increased importance of H_2S in the fluid, especially at higher T, leads to $X(H_2O)$ becoming significantly less than 1, and demonstrates the invalidity of assuming $P(H_2O) = P(\text{fluid})$ for such a pelite (e.g., $X(H_2O$ = 0.30 at P(fluid) = 1 Kb, T = 600°C, compared to $X(H_2O)$ = 0.65 for the sulphide-free system). The lower values of $X(H_2O)$ requires recalculation of the stability fields of hydrous phases in $P\text{-}T\text{-}f(O_2)$ space, which are reduced in size by the lower values of $X(H_2O)$. (Authors' abstract)

POWELL, R. and HOLLAND, T.J.B., 1988, An internally consistent data set with uncertainties and correlations; 3, Applications to geobarometry, worked examples and a computer program: J. Metam. Geol., v. 6, no. 2, p. 173-204. Indexed under "Fluid Inclusions." (E.R.)

PRASOLOV, E.M. and TOLSTIKHIN, I.N., 1987, Juvenile He, CO_2, CH_4: Their proportions and contributions to crustal fluids: Geokhimiya, no. 10, p.

1406-1414 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 5, p. 43-50).

PRASOLOV, E.M., TRAVNIKOVA, L.G., LOBKOV, V.A. and SUBBOTIN, Ye.S., 1987, Isotope compositions of carbon and nitrogen from evaporite gases: Geokhimiya, no. 4, p. 524-532, 1987 (in Russian; translated in Geochem. Int'l., v. 24, 1987 [copyright 1988], p. 53-61). Authors at All-Union Petroleum Surveying Res. Inst., Leningrad, USSR.

Isotope compositions of molecular N and for C in gases (CH_4, C_2H_6 and CO_2) and organic matter OM in evaporites have been examined in the Pripyat depression and other regions. The mean $\delta^{15}N$ (4‰) is close to that for fossil organic matter. The methane formed in the salts has $\delta^{13}C$ -28‰, which differs considerably from the -50 to -30‰ characteristic of gases from sediments. The salt beds cannot have been a substantial gas source that led to the formation of [the gas?] pool. The $\delta^{13}C$ for ethane, OM, and CO_2 are -27, -23, and -7‰. The separation of C isotopes in the CH_4-C_2H_6-OM system is slight, as is that of N isotopes in the N_2-OM system, probably because the OM in the salts is transformed by radiation, not by pyrolysis. The evaporites in salt-tectonic regions, at areas of rapid gas production, are permeable to the gases: $\delta^{13}C$ for the epigenetic methane in the evaporites at -46‰ is close that in the pool gases. Light methane (-56‰) occurs also in salt-stratum replacement zones. A model is given for the formation of the gases in the evaporites on the basis of the isotopic data, together with their trapping, generation and loss. (Authors' abstract)

PRATT, L.M. and BURRUSS, R.C., 1988, Evidence for petroleum generation and migration in the Hartford and Newark basins: U.S. Geol. Survey Bull. 1776, p. 74-79.

Field evidence and fluid-inclusion studies indicate that petroleum and aqueous fluids repeatedly migrated through fracture networks during deformation of the Hartford and Newark basins. Zoned veins, formed by multiple phases of calcite and bitumen precipitation, as well as petroleum in fluid inclusions, provide a record of these migration events. Th of petroleum inclusions indicate T during migration near 100°C and are consistent with levels of thermal maturation inferred from organic maturation indices. The distribution of saturated hydrocarbons is remarkably similar for extracts from shale, solid bitumen in veins and fractures, and viscous petroleum in concretions. We infer that the organic-matter-rich lacustrine shales and siltstones in these basins were effective petroleum source rocks. (From the authors' abstract by E.R.)

PRETORIUS, A.I. and VAN REENEN, D.D., 1988, Fluid inclusion studies of gold deposits in the Sutherland greenstone belt, South Africa (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 461-463. Authors at Dept. Geol., RAU, P.O. Box 524, Johannesburg, 2000, South Africa.

Three types of fluid inclusions are common to the Fumani, Klein Letaba and New Union mines: 1) two-phase, low-salinity, aqueous inclusions, often containing an anisotropic dm; 2) single-phase CO_2 inclusions which nucleate a bubble upon cooling; and 3) low salinity mixed H_2O-CO_2 inclusions with ~35 vol % CO_2 and the same dm. The mixed H_2O-CO_2 inclusions did not form as a result of unmixing of a coexisting H_2O and CO_2 fluid upon cooling but were trapped during the intersection of CO_2-bearing inclusion trails by H_2O-bearing inclusion trails. This observation is also supported by the similar composition of CO_2 in the CO_2 inclusions and in the mixed inclusions.

The presence of CH_4 (or N_2) in CO_2 inclusions at both Fumani and Klein Letaba is indicated by a Tmf[sic] of -58.8°C while CO_2 inclusions at New

Union melted close to the triple point of pure CO_2 (-56.6°C). The CO_2 Th (into liquid) at New Union were close to the critical T of 31°C (Roedder, 1984) whereas Th for Fumani and Klein Letaba were in the range +1°C to 20°C. The lower Th at Fumani and Klein Letaba is partly attributed to the presence of CH_4 (or N_2) in the inclusions.

The observed decrease in the CH_4 content of CO_2 inclusions from Fumani and Klein Letaba in the south, to New Union in the southern marginal zone of the Limpopo belt, is accompanied by an increase in the grade of metamorphism. This relationship supports the suggestion that the associated fluids were metamorphic in origin and that the Au deposits in the Sutherland belt were probably derived from the meta-volcanic pile during the tectonic and metamorphic evolution of the Limpopo belt at 2700 Ma ago. (From the authors' abstract)

PRIKRYL, J.D., POSEY, H.H. and KYLE, J.R., 1988, A petrographic and geochemical model for the origin of calcite cap rock at Damon Mound salt dome, Texas, U.S.A.: Chem. Geol., v. 74, no. 1-2, p. 67-97.

Indexed under "Fluid Inclusions." (E.R.)

PROKOF'EV, V.Yu., BORTNIKOV, N.S. and IGNATENKO, K.I., 1988, Zoning in the Zyryanov pyrite-polymetallic ore deposit based on data for variable-composition minerals and fluid inclusions: Geol. Rudn. Mestorzhd., v. 30, no. 6, p. 91-99 (in Russian).

The tetrahedrite-tennantite ores formed at 200-240°C. (E.R.)

PROKOFIEV, V.Yu. and RYABENKO, S.V., 1988, Conditions of formation of gagarinite from fluid inclusion data: Dokl. Akad. Nauk SSSR, v. 300, no. 3, p. 676-

Th values for gagarinite samples are: 370-375, 415-455, 285-380, 360-425 and 370°C; associated cryolite: 205-250, 120-150, and 170-215. (E.R.)

PROKOF'YEV, V.Yu. and NAUMOV, V.B., 1987, Geochemical features of the mineralizing solutions at the Zyryanov sulfide-polymetallic deposit, Rudnyy Altay: Geochem. Int'l., v. 24, no. 10, 1987, p. 50-60; translated from Geokhimiya, v. 3, 1987, p. 375-38 (abstract by A.W.H., Min. Abst., v. 39, p. 598-599, 1988).

Thermometric and cryometric studies of fluid inclusions in calcite and sphalerite have been made for massive polymetallic ores and country chlorite-carbonate rocks at the Zyryanov sulphide-polymetallic deposit, which have shown that the mineralizing solutions had a high-P (1.6-3.1 kbar) from 145 to 360°C, while they contained the chlorides of Mg, Na and K (concentrations from 8 to 18 wt.% eq. of NaCl), considerable amounts of CO_2 and CH_4 (up to 5.9 and 1.4 mol%/kg, respectively), and more complicated hydrocarbons. The fO_2 calculated from CO_2-CH_4 equilibrium decreased from 10^{-31} to 10^{-47} as the T fell from 360 to 170°C. All the parameters decreased over time (from the early assemblages to the late ones) and in space (for the center of the deposit to the periphery).

PROKOF'YEV, V.Yu., SEMENOV, Yu.V., RYABENKO, S.V. and KORYTOV, F.Ya., 1987, Hydrothermal conditions of formation of mineral assemblages containing cryolite: Geochem. Int'l., 1988, v. 25, no. 1, p. 62-79).

Translation of full paper abstracted in Fluid Inclusion Research, v. 20, p. 318. (H.E.B.)

PROL-LEDESMA, R.M. and BROWNE, P.R.L., 1988, Fluid inclusion analysis in core samples from the Los Humeros geothermal field, Mexico: Geother. Resources Council, Transactions, v. 12, p. 197-202. First author at Inst. de Geof. & DEPFI, UNAM., Cd. Univ. 04510 Mexico.

The results obtained with the data for fluid inclusions from the Los

Humeros geothermal field indicate a zonation in the hydrothermal activity. This zonation has been observed also in the studies of alteration minerals carried out for core and cuttings samples from the exploration wells. The three calderas contained within the field are characterized by different hydrothermal regimes that can be identified on the basis of the fluid inclusion data. The hottest part of the field is located in the central area, where the main outflow from the reservoir may be inferred. The T outside of the central area are related to the presence of the main faults. The thermal regimes determined with the fluid inclusion data are supported also by the alteration mineralogy observations. (Authors' abstract)

PRYOR, M.J., 1988, Geological and fluid inclusion studies at Ogofau and Gwynfynydd gold mines, Wales: S. Afr. J. Geol., v. 91, no. 4, p. 450-464. Author at Anglo Am. Prospecting Svcs., P.O. Box 2515, Nelspruit 1200, Republic of S. Africa.

Integrated mineralogical and fluid inclusion studies of the Ogofau and Dolgellau Au provinces in Wales suggest similar environments of ore deposition. At Ogofau and Gwynfynydd mines there is a close association of Au with carbonaceous pyritic shales, which produced a source of reduced S leading to destabilization of Au-bearing chloro-complexes, allowing precipitation of Au and base metal sulphides. Tt under a lithostatic P of 1.4 to 2.0 kb indicate a range of 350 to 400°C, while Tm range of -0.9 to -2.5°C represents low to moderate salinities with minor CO_2 ($\simeq$ 0.1 mol %) during the deposition of Au. Isotope data, σ ^{34}S indicates a uniform isotopic environment while σ ^{18}O results indicate that the Au mineralizing events were of similar T and/or fluid isotopic composition. The mineralization is related to Caledonide deformation responsible for the formation of fractures through which hydrothermal fluids could ascend, and where fractures intersected pyritic shale horizons Au was precipitated. (Author's abstract)

PURCELL, F.J. and HEINZ, R.E., 1988, FT-Raman and IR absorption spectroscopy: A combined system for the analytical laboratory: Amer. Lab., v. 20, no. 8, p. 34-38.

The combination procedure is particularly valuable to avoid fluorescence problems. (E.R.)

PÜTTMANN, W., HAGEMANN, H.W., MERZ, C. and SPECZIK, S., 1988, Influence of organic material on mineralization processes in the Permian Kupferschiefer Formation, Poland: Org. Geochem., v. 13, no. 1-3, p. 357-363. First author at Lehrstuhl für Geol., Geochemie und Lagerstatten des Erdols und der Kohle, RWTH Aachen, Lochnerstr. 4-20, 51 Aachen, FRG.

The Permian Kupferschiefer horizon in southwest Poland acted as a geochemical trap by accumulating metals from an ascending oxidizing brine. The H-rich organic material in the Kupferschiefer supplied sufficient reduction equivalents for the precipitation of base and precious metals from these brines by redox reactions. This is indicated by regular changes in the molecular composition of the extractable organic material in a set of samples collected from a 1.4 m thick horizon in a Polish mine.

The degree of oxidation is shown to change drastically from the bottom to the top of the horizon. In the bottom section, saturated hydrocarbons are diminished and heteroaromatic systems containing O and S are enriched significantly; alkylated aromatic hydrocarbon abundances are relatively low. The ratio of phenanthrene/sum of methylphenanthrenes varies with the degree of oxidation. Spectral fluorescence measurements reveal an increase in fluorescence intensities of the extracts with increasing oxidation. Moreover, the green shift of fluorescence maxima is related to oxidation effects. Parallel to the intensity of oxidation, as observed from changes in the extractable organic matter, the content of Cu and Ag changes within the horizon. The results confirm that organic matter in sediments, under appropriate geological conditions, can play a significant role in ore formation processes. (Authors' abstract)

PYRAK-NOLTE, L.J., NOLTE, D.D. and COOK, N.G.W., 1988, Fractal flowpaths through fractures in rock (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A300. First author at Dept. Mat. Sci. & Min. Engrg., Univ. California, Berkeley, CA 94720.

Fluids flowing through fractures in rock encounter a complicated topology of tortuous flowpaths and varying apertures. Some insight into the effects that the flowpath topology has on the fluid flow can be gained by using fractal dimensions to describe the geometry of the space between the two rough surfaces of a fracture through which the fluid must flow. The void volume in the fracture is not randomly distributed. Rather, the void spaces and asperities form dense clusters. The fractal analysis of the flowpaths can give a quantitative measure of the degree of clustering. In turn, this clustering of the void-space geometry yields aperture distributions that are correlated with the contact area. This interplay between contact area and aperture determines fluid transport through a fracture. We will present a simple graphic model that accurately mimics measured flowpath patterns in fractures. The model explicitly uses the fractal dimension to cluster voids and asperities and from this to obtain realistic aperture distributions. The effects of stress on fluid flow through a fracture are also included in the model in a simple way. (Authors' abstract)

RAFAL'SKIY, R.P., KONDRASHIN, I.B. and BRYZGALIN, D.V., 1987, Sulfide solubilities in chloride solutions up to 500°C: Geokhimiya, no. 9, p. 1312-1325 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 4, p. 80-94). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Measured instability constants for lead chloride complexes up to 250°C have been used with an equation based on the electrostatic electrolytic-dissociation model in an extrapolation to 500°C. Published sulfide-solubility data have been used to determine the equilibrium constants in the dissolution of PbS and FeS_2. These calculated constants have been used to derive the solubilities of galena and pyrite over a wide range of conditions. The calculated values and published measurements show that the stoichiometric solubilities of the sulfides in weakly acid chloride solutions are of the order of grams per kg H_2O at 400-500°C. (Authors' abstract)

RAGAN, V.M. and COVENEY, R.M., Jr., 1988, Zinc mineralization in the Prescott deposit and adjacent country rocks of Linn County, Kansas (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, p. 126. Authors at Geosci. Dept., Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

The Prescott Zn deposit, a Mississiippi Valley-type (MVT) occurrence in Linn County, Kansas, contains sphalerite in pipes associated with the Mulberry (Penn.) coal. Other MVT occurrences in the area include the Jumbo mine and sphalerite in coal. In addition, nearby oil-bearing limestones contain sphalerite, calcite, chalcopyrite, pyrite, kaolinite, quartz, and dolomite. Elongate P oil inclusions are in sphalerite, which is much more common at the Prescott than at the Jumbo. Oil inclusions also occur in calcite and dolomite.

(Continued)

Th for oil and aqueous fluid inclusions from Linn County, are in the range of 61 to 126°C. Te are -33 and -58°C indicating the likely presence of $CaCl_2$ and $MgCl_2$ in the included brines. This is consistent with Schoewe's (1943) disclosure that brines in Kansas contain Na, Ca, and Mg chlorides. Average Tm are -21.0°C showing approximately 23 eq. wt.% NaCl.

In Linn County, mineralization occurs in breccias, probably formed by simultaneous mineralization and solution. MVT occurrences in Linn County may be the result of metal-bearing, acidic oil field brines which reacted with carbonate host rocks. (Authors' abstract)

RAITH, Michael, HENGST, C., NAGEL, B., BHATTACHARYA, A. and SRIKANTAPPA, C., 1988, Metamorphic conditions in the Nilgiri granulite terrane and the adjacent Moyar and Bhavani shear zones; a reevaluation: Workshop on the Deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 138-139. (Also in J. Geol. Soc. India, v. 31, no. 1, p. 112-113.)

Indexed under "Fluid Inclusions." (E.R.)

RAITH, Michael, KLATT, E., SPIERING, B., SRIKANTAPPA, C. and STAEHLE, H.J., 1988, Gneiss-charnockite transformation at Kottavattam, southern Kerala, India: Workshop on the Deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 140-141. (Also in J. Geol. Soc. India, v. 31, no. 1, p. 114-115.)

Indexed under "Fluid Inclusions." (E.R.)

RAITH, Michael, STAEHLE, H.J. and HOERNES, H., 1988, Kabbaldurga-type charnockitization; a local phenomenon in the granulite to amphibolite grade transtion zone: Workshop on the Deep continental crust of South India, Bangalore, India, Jan. 9-23, 1988, LPI Tech. Rept. 88-06, p. 142-143. (Also in J. Geol. Soc. India, v. 31, no. 1, p. 116-117.)

Indexed under "Fluid Inclusions." (E.R.)

RAMBOZ, C., 1988, Hydrothermal metamorphism and redox reactions in passive margins and ductile shear zones: Implications for the origin of associated Zn-Pb and graphite mineralization: Ph.D. dissertation, Inst. Natl. Polytech. de Lorraine (and CRPG, CNRS), Nancy, France.

The thesis is a collection of five independent original papers concerning fluid-rock interaction processes in passive margin environments and ductile shear zones. All other abstracts and papers published by the author between 1982 and 1987 are collected as an Appendix.

- Chapter I (by C. Ramboz, in English) presents crystal chemical evidences for the presence of nonstoichiometric ferric pyroxenes associated with silic-deficient garnets formed at very low fO_2-conditions in graphite-rich skarns from Sidi Bou Othmane (Eastern Meseta, Morocco).
- Chapter II (by C. Ramboz and A. Charef, Econ. Geol., v. 83, 1988) presents fluid inclusion evidence for transient abnormal fluid P ('superpressures') at Les Malines on the Cevenole margin (France).
- In Chapters III and IV, the T conditions of brine discharge at the bottom of Atlantis II Deep (Red Sea)) are made more precise, based on the study of fluid inclusions in epigenetic anhydrites in hydrothermal sediments (evidence for boiling on the sea floor is provided: C. Ramboz, E. Oudin and Y. Thise, Canad. Mineral. 26/3, 1988) and on the heat-mass balance of the Deep over 20 years (C. Ramboz and M. Danis, submitted to E.P.S.L.).
- Finally, Chapter V (C. Ramboz, in French) presents a characterization of the mechanisms of fluid circulation and mineralizations in passive margins at the various stages of their evolution. (Author's abstract)

RAMBOZ, Claire and CHAREF, Abdelkrim, 1988, Temperature, pressure, burial history, and paleohydrology of the Les Malines Pb-Zn deposit: Reconstruction from aqueous inclusions in barite: Econ. Geol., v. 83, p. 784-800. First author at Centre de Recherches Pétrogr. & Géochim., B.P. 20, 54501-Vandoeuvre-lès-Nancy, France.

Aqueous inclusions in oil-bearing vug-filling barite which postdates the karstic and fissural ore stages at Les Malines, one of the largest Mississippi Valley-type Zn-Pb deposits in Europe, have been studied by microthermometry and Raman spectrometry. The correlative variations of Tm ice and of Th define three main stages: (1) stage I, gas-rich inclusions characterized by Tm ice = -7° ± 1°C and Th L-V(V) = 180° to 380°C, (2) stage II, liquid-rich and gas-rich inclusions homogenized in the T range of 160° to 175°C, with Tm ice = -8.2° to -4.1°C -- stage I and stage II inclusions contain CO_2 and no CH_4, N_2, or H_2S detectable by Raman spectrometry, and (3) stage III, liquid-rich inclusions, characterized by Tm ice which increased from -8° to -1.7°C as their Th L-V(L) decreased from 160° to 130°C. They are essentially aqueous.

The H_2O-CO_2-NaCl vapor-dominant stage I inclusions in barite cannot have leaked because their gas content is distinct from air. They are interpreted to have trapped a hot (T ~300°C), CO_2-bearing vapor which was cooling. Oil was thermally degraded during trapping in barite. The source of heat and CO_2 is considered to be volcanism contemporaneous with the major uplift of the horst during the Upper Jurassic. Dissolution of the carbonate wall rock is related to stage I. Stage II inclusions are interpreted to represent the end-product of the mixing of pore fluid with the hot vapor. The T of the pore fluid exceeded 150°C prior to the addition of magma-heated fluids. Such anomalous pore fluid T are tentatively related to the steady dewatering of the Terres Noires shales from below, with the fluids moving up along the east-west fault of Les Malines near adiabatic conditions. The formation waters were probably responsible for the migration of the oil and for the recrystallization of the basement. Gas-rich and liquid-rich stage II inclusions are compatible with minor unmixing of the H_2O-CO_2-NaCl liquid with precipitation of calcite. The $\bar{V}$-X properties calculated for a stage II liquid-rich inclusion (96.1 mole % H_2O, 1.85 mole % NaCl, and 2 ± 0.2 mole % CO_2; $\bar{V} = 21.5 \pm 1.3$ cm^3 mole^{-1}) fix the P of unmixing at 175°C in the range 285 ± 45 bars. The Th-$\bar{V}$-X properties of secondary CO_2-bearing inclusions in barite from the earlier fissural stage (Charef and Sheppard, 1988) point to higher fluid P in the horst, in the range of 365 ± 45 bars minimum. CO_2-rich inclusions in the two barite generations imply that the metamorphosed Cambrian basment at Les Malines has been transiently geopressured below the Triassic shales. The addition of a small amount of magma-derived CO_2 to the pore fluid probably accounts for the rapid increase of P. The fluid P in the horst reached near-lithostatic values repetitively, first at the end of the Middle Jurassic subsidence, when the burial depth was around 1,600 ± 200 m, then at a later stage, probably during the Upper Jurassic, when the sedimentary cover was partly eroded to around 1,200 ± 200 m. The overpressuring, with a possible structural deformation resulting from the rising magma, probably caused the opening of the vertical, late barite-filled veins by hydraulic fracturing. Stage III inclusions are interpreted to indicate the influx of colder diluted fluid to the horst under hydrostatic P conditions, i.e., after decompression. (Authors' abstract)

RAMBOZ, Claire, OUDIN, Elisabeth and THISSE, Yves, 1988, Geyser-type discharge in Atlantis II Deep, Red Sea: Evidence of boiling from fluid inclusions in epigenetic anhydrite: Canadian Mineral., v. 26, p. 765-786. First author at Centre de Recherches Petrogr. & Géochim., B.P. 20, 54501-

Vandoeuvre-lès-Nancy, France.

Anhydrite crystals in veins at the base of a drill core from SW Basin sediment, Atlantis II Deep, Red Sea, contain in their core tubular P two-phase aqueous inclusions which are either liquid- or vapor-dominant (type L and V, respectively). Type-L inclusions yield Tm(ice) of between -20.4 and -4.4°C, and Th of liquid [Th L-V(L)] in the range 55 to 420°C. Type-V inclusions show Tm(ice) values between -12 and -5°C, and Th LV(V) values between 324 and 430°C. Some crystal overgrowths contain more isometric NaCl-saturated P inclusions. These are characterized by Tm(halite) and Th LV(L) values ranging from 50 to 283°C and 185 to 405°C, respectively; some supersaturated inclusions are characterized by Th LV(L) values between 84 and 404°C. Type-L inclusions from crystal cores, with salinities <19 wt.% eq. NaCl, show a decreasing salt content with increasing molar volume. Such V-X properties are characteristic of inclusions containing heterogeneous mixtures of liquids and vapors generated by boiling; these inclusions were slightly cooled before trapping. Type-L inclusions with salinities in the range 19-23 wt.% eq. NaCl result from homogeneous trapping. They consist of four populations with lognormal distributions of the Tm(ice) values, and define four vertical trends in a V-X plot which are parallel to those defined by saturated and supersaturated inclusions. Two inclusions from these trends, with maximum Th values of 388 and 403°C and salinities of 21.3 and 32.6 wt.% eq. NaCl, respectively, yield an internal P at T = Th which is within 10 bars of the in situ hydrostatic P on the sea floor (i.e., 223 ± 2 bars); this indicates that boiling took place. The fluid-inclusion data are consistent with an initial brine of ≈ 19 wt.% eq. NaCl, and with an enthalpy around 1950 J/g, which became enriched in salt to ≈ 33 wt.% eq. NaCl through loss of vapor. Near-isothermal long-duration boiling of solutions implies a deep fluid reservoir with a limited volume, and heated by a magma. The salt-enriched liquids were injected intermittently on the sea floor, then cooled without mixing. These data and mineralogical observations suggest that epigenetic anhydrite is the product of interaction of the fluid and the hematitic sediment, i.e., of redox reactions involving Fe^{2+}/Fe^{3+} and $\Sigma S^{2-}/\Sigma SO_4^{2-}$. (Authors' abstract)

RAMSEYER, K., BAUMANN, J., MATTER, A. and MULLIS, J., 1988, Cathodoluminescence colors of α-quartz: Mineral. Mag., v. 52, p. 669-677. First author at Geol. Inst., Baltzerstr. 1, Univ. Bern, 3012 Bern, Switzerland.

A new cathodoluminescence-microscope has been developed with a considerably improved detection limit. Time-dependent luminescence intensity changes observed during electron bombardment enabled the recognition of short-lived, long-lived, and brown luminescence color types in α-quartz.

Short-lived bottle-green or blue luminescence colors with zones of non-luminescing bands are very common in authigenic quartz overgrowths, fracture fillings or idiomorphic vein crystals. Dark brown, short-lived yellow or pink colors are often found in quartz replacing sulphate minerals. Quartz from tectonically active regions commonly exhibits a brown-luminescence color. A red luminescence color is typical for quartz crystallized close to a volcanic dike or sill.

The causes of these different and previously poorly understood luminescence colors were investigated using heat treatment, electron bombardment and electrodiffusion. Both natural and induced brown luminescence colors reflect the presence of lattice defects (nonbonding Si-O) due to twinning, mechanical deformation, particle bombardment or extremely rapid growth. The bottle-green and blue linearly polarized luminescence color, characterized by a plane of polarization parallel to the c-axis, both depend on the presence of interstitial cations. The yellow and red luminescence colors in α-quartz both exhibit a plane of polarization perpendicular to the c-axis and appear to be related to the presence of trace elements in an oxidizing solution and to ferric iron respectively. (Authors' abstract)

RANAWAT, P.S., 1986, Fluid inclusion study of fluorites from Asind, Rajasthan: Seminar on evolution of the Prec. crust in the Aravali Mt. belt, Abst. of papers, p. 58-59. Author at Univ. Rajasthan.

Narrow veins of fluorspar occur as fissure or joint filling in Precambrian migmatites near Asind (Bhilwara District). The area is essentially a migmatite terrain with intrusives of amphibolite, pegmatite and aplite. Veins and bands of epidosite and unakite are commonly observed. Fluorite is violet, purple or colorless granular and is rarely associated with quartz. Epidotization of vein walls is characteristic feature observed in the area. Fluorite contains multiphase P and PS fluid inclusions having an aqueous phase + vapor bubble + NaCl ± granular and/or acicular birefringent phase ± black opaque phase. The aqueous phase has RI nearly equal to that of fluorite, but the outline of the inclusion cavity (mostly irregular) becomes clear during heating and freezing runs. Type II inclusions have a distinct relief and have only halite dm. Type III inclusions also have distinct relief but are biphase. Quartz also contains multiphase or three-phase inclusions. The fluid in inclusions freezes with difficulty to a dark brown phase; freezing commences and ends in dendritic fashion. Cryometric data are Te: -57 ± 2°C, Tm hydrohalite: -50 ± 5°C, Tm ice: -24 ± 2.5°C. During the heating runs L/V homogenization usually takes place before dissolution of dms. Th L-V: 132°-187°C, Th NaCl: 120°-164°C, Th birefringent phase: 205°-262°C, the inclusions decrepitate before total homogenization. Inclusions near the top of the plate on decrepitation leave a brown residue on the surface of the plate. The fluid inclusion and field studies show that the fluorspar mineralization in the area was brought about by concentrated solutions having high $CaCl_2$/NaCl ratio (presence of Fe salts is also indicated) having minimum T of about 400°C and minimum P of about 1.5 kb. The fluorspar mineralization is possibly an outcome of late stage activity related to migmatization of the rocks of the area. (Author's abstract)

RANAWAT, P.S., BHATNAGAR, S.N. and SHARMA, N.K., 1986, Metamorphic consideration of Rampura-Agucha lead-zinc deposit: Seminar on evolution of the Prec. crust in the Aravali Mt. belt, Abst. of papers, p. 50-51. First author at Univ. Rajasthan.

Ore mineralization at Rampura-Agucha is represented by sphalerite, pyrrhotite, pyrite, flaky graphite and galena with minor amounts of chalcopyrite and arsenopyrite. The ore minerals are hosted essentially in Precambrian sillimanite bearing quartzo-feldspathic gneisses and mica schists and partly in calc-silicates. Fluid inclusions in the minerals of the host rocks are too small for microthermometry. Quartz and tourmaline from pegmatite contain low density CO_2-CH_4, and aqueous inclusions. Data of these fluid inclusions have been utilized to understand the P-T path followed during uplift. (From the authors' abstract by H.E.B.)

RANAWAT, P.S., BHATNAGAR, S.N. and SHARMA, N.K., 1988, Metamorphic character of Rampura-Agucha lead-zinc deposit, Rajasthan, in A.B. Roy, ed., Precambrian of the Aravalli Mountain, Rajasthan, India, Memoir 7: Geol. Soc. India, p. 397-409. First author at Dept. Geol., Univ. Rajasthan, Udaipur-313 001, India.

Ore mineralization at Rampura-Agucha is represented by sphalerite, pyrrhotite, pyrite, and galena with minor amounts of chalcopyrite, arsenopyrite, falhore and boulangerite. The ore minerals are hosted essentially in the Precambrian graphite-sillimanite-bearing quartzo-feldspathic gneiss and schist, and calc-silicate rocks. Petrography of drill-core samples shows that the ore minerals have been metamorphosed together with the host rocks under upper amphibolite facies conditions at P and T in the order of 6.2 ± 0.4 kb and 680° ± 30°C, respectively. Quartz and toumaline from pegmatite contain independent $CO_2(+CH_4)$ and aqueous fluid inclusions. Intersection of CO_2 and H_2O isochores shows that the tourmaline and quartz in pegmatite formed at a much later stage (300°C and 0.64 kb). Substantial part of footwall side of the ore body was involved in dynamic metamorphism subsequent to regional metamorphism. (Authors' abstract)

RANKIN, A.H., 1988, Fluid inclusion steam aureoles associated with granite-hosted mineralization: Geol. Soc. India Memoir 11, p. 45-58. Author at Dept. Geol., Royal Sch. Mines, Imperial College, London SW7 2BP, UK.

Anomalous fluid inclusion populations may exist in apparently unaltered granite host-rocks surrounding zones of hydrothermal alteration and mineralization. These anomalous areas, referred to as steam aureoles, result from the infiltration and outward migration of hydrothermal fluids into the country rock via microfractures with the concomitant development and addition of S fluid inclusions to the granite quartz as these fractures are healed. Examples from mineralized granites of France and Australia show that these aureoles may be characterized by a progressive increase in fluid inclusion abundances which can extend several tens of meters beyond the zone of visible alteration. Present difficulties, however, in analyzing the trace and ore metal contents of fluid inclusions mean that the important distinction between aureoles surrounding metalliferous and barren hydrothermal mineralization is extremely difficult. Existing, low-cost fluid inclusion methods such as optical examination and decrepitometry should be fully integrated, therefore, with other exploration techniques to maximize their usefulness. (Author's abstract)

RANKIN, A.H. and GRAHAM, M.J., 1988, Na, K and Li contents of mineralizing fluids in the Northern Pennine Orefield, England, and their genetic significance: Trans. Instn. Min. Metall. (Sect. B: Appl. earth sci.), v. 97, p. B99-B107. Author at Royal Sch. Mines, London, England.

New determinations of the Na:K and Na:Li ratios of fluid inclusions from the central fluorite zone of the Alston Block are used in conjunction with empirical alkali geothermometers to provide estimates of T in the source region of the mineralizing fluids. The Na:K weight ratios determined by inductively coupled plasma (ICP) analysis of leachates and decrepitates are similar to those previously published and range from 7.0 to 14.2. These data are compatible with equilibration T at source of between 150° and 250°C, some 50°C higher than the reported Th for the area. The Na:Li weight ratios range from 240 to 650. Application of the Na:Li geothermometer gives anomalously high T (240°-440°C). A mechanism whereby basinal brines increase their Li contents through interaction with the Li-enriched Weardale granite is proposed to explain the high Li contents of the mineralizing fluids compared with modern-day oil field and coal field brines and to explain the evolution of fluids responsible for fluorite mineralization in the Alston Block. (Authors' abstract)

RANOROSOA, Nadine, 1987, Mineralogic and microthermometric studies of pegmatites of the Sahatany area - Madagascar (abst.): PhD dissertation, Univ. Paul Sabatier, 39 Allees Jules Guesde, 31400 Toulouse, France (in French; translated by R.P. Moritz).

The Sahatany pegmatite field of Panafrican age in Central Madagascar is located in a series of metasediments with an evaporitic affinity. Following a mineralogical study of the pegmatites, a microthermometric study of fluid inclusions in quartz, topaz, and spodumene has permitted definition of the conditions of crystallization, and to characterize the nature of the fluids. Melting T below -40°C indicate the presence of Ca, Li, and Mg in addition to Na and K. Salinities range between 0 and 15% NaCl depending on the mineralogy of the pegmatite. Pegmatites located in micas schists and quartzites contain aqueous and low-salinity inclusions, whereas inclusions are CO_2-rich in pegmatites located in carbonate rocks. P-T conditions of formation were between 350 and 500°C, and between 2000 and 3000 bars. Late stage CO_2-bearing inclusions indicate P-T conditions around 300°C and 1000 bars. (From the author's abstract)

RAVENHURST, C.E., REYNOLDS, P.H. and ZENTILLI, Marcos, 1988, Low-temperature thermochronology of central Nova Scotian Pb-Zn and Ba deposits by fission-track, K-Ar and $^{46}Ar/^{39}Ar$ techniques: GAC/MAC Prog. and Abstracts, v. 13, p. A103.

See next item. (E.R.)

RAVENHURST, C.E., REYNOLDS, P.H., ZENTILLI, Marcos, KRUEGER, H.W., and BLENKINSOP, J., 1988, An isotopically and thermochronologically constrained model for late Paleozoic Pb-Zn and Ba mineralization in Nova Scotia, Canada (abst.): Geol. Soc. Amer., Abstract with Programs, v.20, n.12, p.64, First author at Dept. of Geol., Dalhousie Univ., Halifax, Canada.

Mississippi Valley-type Pb-Zn and Ba deposits in Nova Scotia generally occur at the Tournaisian-Visean clastic-carbonate/evaporite disconformity overlying Cambrian to Devonian metasedimentary and granitic rocks.

Fluid inclusion Th of ore-stage to post-ore minerals range from 250° to 140°C and fluid salinity is ≈24 eq. wt.% NaCl. Zircon fission track dates are 313±44(2σ) Ma for the Gays River Zn-Pb deposit and 250±34 (2σ) Ma for the Smithfield Pb-Zn-Cu-Ba deposit (both open-space fill). Preliminary K-Ar dates on illite associated with mineralization, also support ≈300 Ma heating event. Illite samples from a 10 m section of Tournaisian clastic rocks (away from mineralization) define a 300±6 Ma Rb-Sr isochron. Pb and Sr isotope data indicate that Tournaisian rock could have been a source (at 300 Ma) for galena mineralization and for radiogenic strontium ($^{87}Sr/^{86}Sr$=0.712) in ore-stage minerals at the larger deposits. Visean carbonate C and sulfate were the dominant sources of C and S. Non-biogenic sulfate reduction is the likely sulfide precipitation mechanism. H and O isotopic data support a basinal brine source. Compaction-driven episodic expulsion of brines by a hydrofracturing mechanism is the genetic model supported by our data. (From the authors' abstract)

REDDY, D.C., RAO, N.K. and ANANTHASWAMY, J., 1988, Thermodynamics of electrolyte solutions: Electromotive force studies on aqueous solutions of KCl in KCl + $MgCl_2$ + H_2O system at 25°C: Current Sci., v. 57, no. 6, p. 287-290. Authors at Dept. Chem., Osmania Univ., Hyderabad 500 007, India.

The activity coefficients of aqueous KCl in KCl-$MgCl_2$-H_2O system were obtained at 25°C and at total ionic strengths of 0.5, 1, 2 and 3 m by an emf method using potassium ion-selective electrode and Ag/AgCl electrode. The activity coefficient data were fitted to the Harned equation and the Harned coefficients evaluated. The data were also analyzed using the Pitzer equations and the corresponding binary and ternary interaction parameters were estimated. (Authors' abstract)

RED'KIN, A.F., IVANOV, I.P. and OMEL'YANENKO, B.I., 1988, Solubility of uranium dioxide in acid chloride fluids at 400-600°C and 1 kbar: Dokl. Akad. Nauk SSSR, v. 299, no. 3, p. 726-729 (in Russian). First author at Inst. Experimental Mineralogy of Acad. Sci. USSR, Chernogolovka near Moscow, USSR.

The solubility of uranium dioxide m_u at fO_2 controlled by Ni/NiO buffer and at T 400-600°C, P 1 kbar, is described by the following equations (m(HCl) - concentration of hydrochloric acid in solution):

400°C: $m_u = 1.6 \times 10^{-2} \times m^2(HCl) + 10^{-6}$

500°C: $m_u = 10^{-2} \times m^2(HCl) + 10^{-6}$

600°C: $m_u = 10^{-3} \times m^2(HCl)^* + 10^{-6}$; * the Russian text gives here m(HCl), that may be a misprint. (A.K.)

RED'KIN, A.F. and OMEL'YANENKO, B.I., 1987, The solubilities of uranium oxides in water at 773 K and 100 MPa: Geokhimiya, no. 8, p. 1200-1206 (in Russian; translated in Geochem. Int'l., 1988, v. 25, no. 3, p. 120-126).

REED, M.H. and SPYCHER, N.F., 1988, Chemical modeling of boiling, condensation, fluid-fluid mixing and water-rock reaction using programs CHILLER and SOLVEQ (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Authors at Dept. Geol. Sci., Univ. Oregon Eugene, OR 97403.

In geothermal systems, waters boil at depth, precipitating ore sulfide and carbonate minerals; boiled gases, including Hg, condense near the surface where they are oxidized, producing sulfuric acid waters that alter host rocks to clays, or back-react with boiled waters to precipitate As, Sb and Au. This example illustrates the type of complex natural chemical system that SOLVEQ and CHILLER model by computing: Phase assemblage; compositions of the aqueous phase and gas phase, treating CO_2, H_2O, CH_4, and H_2S gases as non-ideal mixtures of real gases; compositions of solid solutions (ideal or non-ideal); distribution of heat among phases. Key computational capabilities that make this possible include: an internal enthalpy balance equation that is solved simultaneously with the chemical mass balance and mass action equations; arbitrary selection of redox couples to provide for calculations over the entire range of natural oxygen fugacities; re-selection of the phase assemblage during the iterative solution process. (Authors' abstract)

REIF, F.G., 1988, Thermobarogeochemical methods in petrology: New data -- new problems, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 3-10 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 338-339. (E.R.)

REIF, F.G., BAZHEEV, E.D., ISHKOV, Yu.M., FIRSOVA, G.N. and BOLDOKHONOVA, T.A., 1988, The theory and practice of predicting W-Mo-mineralization on a thermobarogeochemical basis, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 162-167 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 339. (E.R.)

REN, S.K., EGGLETON, R.A., and WALSHE, J.L., 1988, The formation of hydrothermal cookeite in the breccia pipes of the Ardlethan tin field, New South Wales, Australia: Canadian Mineralogist. v.26, p. 407-412.

Authors at Dept. of Geol., Australian Nat'l. Univ., GPO Box 4, Canberra, ACT 2601, Australia.

Includes histograms of Th (?) and salinity (p.410) showing 140-400°C and 1 to 17 wt. % NaCl eq. (E.R.)

REYES, A.G., 1985, Preliminary evaluation of vitrinite reflectance geothermometry as applied to Pal-8D, Bacon-Manito: Proc. 7th ann. PNOC-EDC Geoscientific Workshop, Vol. 1, Manila, PNOC-Energy Devel. Corp., p. 23-39. Author at Petrbiogist, PNOC-Energy Dev. Corp.

Vitrinite reflectance is an important parameter in the determination of coalification rank or organic metamorphism within the range bituminous to anthracite. This can be applied as a geothermometer in carbonaceous siltstone to calcisiltite formations frequently encountered in Philippine geothermal areas, which are usually bereft of mineral geothermometers or material for fluid inclusion studies. Two core samples from the Gayong formation of PAL-8D were examined together with two cores from Nagawha, New Zealand, and compared with vitrinite reflectance data from Cerro Prieto, Mexico; U.S.A, Japan and other areas in New Zealand.

Vitrinite reflectograms of PAL-8D indicate a single population, i.e., no reworked or oxidized phytoclasts were incorporated in the rocks during deposition, unlike in Ngawha. Mean vitrinite reflectance were plotted on Barker's empirical R_0 % T curve (1979) for Cerro Prieto. For PAL-8D predicted vitrinite T, fluid inclusion Th and measured T coincide. This is unexpected since several episodes of hydrothermal activity are evident in Bacon-Manito and the field had apparently cooled by ~80°C. (Author's abstract)

RICHARDS, J.P., KROGH, T.E. and SPOONER, E.T.C., 1988, Fluid inclusion characteristics and U-Pb rutile age of late hydrothermal alteration and veining at the Musoshi stratiform copper deposit, Central African copper belt, Zaire: Econ. Geol., v. 83, p. 118-139. First author at Res. Sch. Earth Sci., Australian Nat'l. Univ., GPO Box 4, Canberra, ACT 2601, Australia.

Linear zones of particularly intense alteration and veining probably represent structurally controlled fluid conduits. Fluid inclusions in vein quartz from such zones identify an apparently halite-saturated liquid at 397° ± 5°C, with ~39 wt % NaCl, 15 wt % KCl, and minor amounts of CO_2 and other components.

Rutile is found pervasively, both as a wall-rock alteration phase and as large euhedra (up to 3 cm) in the quartz veins. The hydrothermal growth of this normally very insoluble mineral is explained by the high T and salinity of the aqueous phase.

The hydrothermal activity is concluded to be a late overprint, unrelated to Cu ore deposition, but perhaps related to the Lufilian orogeny. (From the authors' abstract)

Daughter phases also include CO_2 liquid, sylvite, barite(?), anhydrite, Fe chloride(?) and a "pseudodaughter" phase hematite. (E.R.)

RICHARDSON, C.K., RYE, R.O. and WASSERMAN, M.D., 1988, The chemical and thermal evolution of the fluids in the Cave-in-Rock fluorspar district, Illinois: Stable isotope systematics at the Deardorff mine: Econ. Geol., v. 83, p. 765-783. First author at Dept. Earth Sci., Iowa State Univ., Ames, IA 50011.

The general paragenetic sequence for the Deardorff mine, and for much of the Cave-in-Rock district, is fluorite, sphalerite, galena, quartz, calcite, and barite, with fluorite spanning the sphalerite, galena, and quartz deposition. Liquid hydrocarbons are observed in fluid inclusions of most minerals but are most numerous in fluorite. Stable isotope data, along with previously published T and salinity data on fluid inclusions, place significant constants on the origin of the fluids responsible for these minerals and on the nature of the hydrothermal system.

Mineralization was dominated by two meteoric recharged formation fluids: a main-stage, saline (19 ± 1 eq. wt % NaCl), high-T (145° ± 5°C) fluid with a $\delta D(H_2O)$ value of -25 ± 5 per mil and a late-stage, more dilute (1-9 eq. wt % NaCl), generally lower T (125° ± 25°C) fluid with a $\delta D(H_2O)$ value of -40 ± 10 per mil. The D enrichment of the main-stage fluid most likely resulted from exchange between formation waters($\delta D \simeq -50‰$) and the basement rocks under low water/rock conditions. Data on secondary fluorite inclusions suggest that the dilute fluids were present in the upper stratigraphic levels of the system during main-stage mineralization. Mixing of dilute and saline fluids in the ore horizon apparently occurred during postore carbonate deposition but not during the portion of the main-stage sequence which occurs at the Deardorff mine. Mixing of two saline fluids appears to have occurred during quartz deposition. The ore and late-stage fluid $\delta^{18}O(H_2O$ values range from -1 to +2 per mil and 0 to 8 per mil, respectively, with both fluids showing a trend to larger values across the paragenetic sequence. This increase in $\delta^{18}O(H_2O)$ values occurred in spite of a decrease in salinity and a general T decline of the late fluids; it probably resulted from continuous equilibration of the fluids with sedimentary carbonates.

The $\delta^{34}S$ values of sulfides (4.0-8.9‰ for sphalerite) are among the lowest recorded for sulfides in Mississippi Valley-type deposits and probably reflect a significant contribution of H_2S from petroleum and possibly igneous or crustal sulfur from the basement. Main-stage galena and sphalerite are generally in sulfur isotope equilibrium at the T of ore deposition. The $\delta^{34}S$ values of later barites range from about 57 to 103 per mil, with some crystals showing systematic increases from the core to the edge of the crystals. These values are completely out of equilibrium with those for earlier sulfides and are believed to be the largest recorded for naturally occurring sulfates. Sulfate $\delta^{18}O$ values, however, range from only 19.6 to 20.8 per mil and were apparently in equilibrium with the hydrothermal fluids. These data suggest that the sulfate derived from a small fluid reservoir where it underwent thermal chemical reduction with organic matter. In a manner consistent with the involvement of organic matter in the late fluids, the $\delta^{13}C(CO_2)$ of the fluids decreased from about -3 to -20 per mil during the carbonate paragenesis. (Authors' abstract)

RIEKEN, R., 1988, Fluid systems and hydrocarbon migration in diagenetic sequences of the Northwest German Basin (abst.): Terra cognita, v. 8, p. 31-32. Author at Inst. Geol. & Dynamik der Lithosphäre, Göttingen, FRG.

Observation of aqueous and hydrocarbon-bearing fluid inclusions in authigenic cements enables differentiation of fluid systems and timing of hydrocarbon migration in the Northwest German Basin. The migration history of fluid systems associated with different hydrocarbon generations during diagenesis has been reconstructed by using microthermometry, Raman microprobe and cathodoluminescence.

For this purpose 40 Mesozoic core samples were collected from 7 wells and 60 Upper Carboniferous core samples from 9 wells out of this basin. Generally, the Th and salinities of the fluid inclusions measured in the authigenic minerals, as quartz overgrowths, carbonate cements and quartz-anhydrite fissure mineralizations, increase with depth. The first melting T of ice [Tm ice or Te?] show similar tendencies and indicate increasing enrichment of bivalent cations as, for example, Ca^{2+} and Mg^{2+} at greater depths. The relic P and S inclusions in detrital quartz can typically be classed as solutions of higher T and low salinities.

The Mesozoic samples from wells A and D provide evidence for a high geothermal gradient between 50 and 60°C/km. This T anomaly is directly related to a magmatic intrusion of which the Bramscher Massif at the southern basinal margin, for example, is a part. The Upper Carboniferous samples, however, show a geothermal gradient of 30°C/km. Consequently, quartz and carbonate authigenesis can be assumed to have still been formed before magmatic heating. Hydrocarbon-bearing inclusions only occur in quartz growth rims of Upper Carboniferous sandstones. First Raman microprobe investigations evidenced that P and PS fluid inclusions only consist of a pure methane phase whereas S inclusions contain higher hydrocarbons, such as ethane, butane and propane.

A model of the genetic process of fluid and hydrocarbon migration has been constructed, respectively, of the Upper Carboniferous sequences. The first hydrocarbon migration took place during the second quartz cementation in the Triassic period with increasing burial. Carbonate cement solution produces secondary porosity which provides favorable conditions for migrations and storage of hydrocarbons. In the course of continuing depression of the seam-bearing Upper Carboniferous in the Triassic and Jurassic period recoalification took place. Probably in the Jurassic-Cretaceous period, rising migration of hydrocarbons created the Upper Carboniferous, Rottiegendes and Lower Triassic gas deposits. (Author's abstract)

RILEY, G.N., Jr. and KOHLSTEDT, D.L., 1988, Melt migration in olivine-basalt systems: Implications for magma transport (abst.): EOS, v.69, p.482.

RIVERS, M.L., SUTTON, S.R. and SMITH, J.V., 1988, Trace element analysis using a synchrotron X-ray fluorescence microprobe: Fortschritte der Mineral., v. 66, p. 135.

The high intensity, natural collimation, continuous spectrum and plane polarization of synchrotron radiation combine to make it an ideal source for an X-ray fluorescence (XRF) microprobe for trace element analysis.

A "first generation" XRF microprobe has been in use at beamline X-26C at the National Synchrotron Lightsource at Brookhaven National Laboratory since March 1986. This microprobe uses white light beam from a bending magnet which is collimated by adjustable tantalum slits and filtered by selectable absorbers. The beam diameter is typically 20-50 microns, with usable fluxes between 3.5 and 30 keV. The sample is mounted on a X-Y-Z-Theta stage in air and is observed with a microscope and video system. The fluorescent X-rays are detected with a Si(Li) detector mounted at 90° to the incident beam in the horizontal plane, which minimizes the background due to scattered photons. Detection limits and usable beam sizes are matrix dependent. For elements from Ti to Sn in geological samples the detection limits range from 0.5 - 1 ppm in silicates and carbonates to 3-5 ppm in sulfide minerals.

Quantitative analysis is performed by first determining peak areas and then correcting for sample thickness, fluorescent yield, absorption and enhancement using the Naval Research Laboratory program NRLXRF. This technique permits prediction of peak area ratios from fundamental parameters, so that if there is a known concentration of a major element in the sample it is possible to perform "standardless" analysis within accuracies better than 30% in most cases. More accurate analyses can be obtained with the use of suitable standards, if they are available.

The fluorescence microprobe at NSLS beamline X-26C has been used for a large number of trace element investigations. These involve sulfides, extraterrestrial materials, carbonates and fluid inclusions. (From the authors' abstract by E.R.)

ROBB, L.J. and MEYER, M., 1988, Uranium distribution in greisenized granites from the Archaean basement in the hinterland of the Witwatersrand Basin (abst.): Chem. Geol., v. 70, p. 190. Authors at Dept. Geol., Univ. Witwatersrand, Johannesburg, RSA.

The Klerksdorp Goldfield is a major producer of uranium (average annual production ≈ 2100 metric tons U_3O_8 having yielded as much U_3O_8 as the remainder of Witwatersrand mines collectively. Palaeocurrent indicators suggest that detritus was derived from a source area that lay to the NW of the Klerksdorp Goldfield. This hinterland is underlain in part by a 3120 Ma old (Armstrong, et al., in prep.), potassic, occasionally peraluminous, granite which commonly exhibits a pervasive style of greisenization. Hydrothermal veins, comprising a quartz-muscovite-chlorite-albite-fluorite-sulphides-kerogen paragenesis, occasionally accompany the greisenization. This occurrence is unusual as very few, if any, examples of this style of alteration are known in Archaean (i.e., >3.0 Ga) granitoids.

Fluid inclusions in the greisenized granites are dominantly H_2O L + V with a small proportion of inclusions containing calcite (J. Dubessy, per. comm.) and possibly halite daughter crystals. The melting behavior of frozen inclusions is markedly incongruent, defining a melt eutectic at circa -52°C and liquidus T in the range -22 to -18°C. Fluid compositions are best modelled in the ternary H_2O-NaCl-$CaCl_2$ system. A homogenization peak for these fluids occurs at approximately 310°C.

Greisenization appears to have resulted in the collective mobilization of U-Th-LREE, a situation similar to that evident in uranium-mineralized peraluminous granites of the French Massif Central (Cathelineau, 1987). In the latter case saline hydrothermal solutions were responsible for the dissolution of the subsequent provision of PO_4^- and Cl^- ligands for the transport of U and LREE respectively. A similar situation may pertain to the present study, although in this case uranium appears to have been reprecipitated as uraninite in association with sulphides or carbonaceous matter. (From the authors' abstract by H.E.B.)

ROBERTS, J.L. and ZANTOP, Half, 1988, Hydrothermal alteration and fluid inclusion studies of the Cazaderos epithermal district, Zacatecas, Mexico (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A278. Authors at Dept. Earth Sci., Dartmouth College, Hanover, NH 03755.

The Cazaderos Ag-Pb-Zn prospect is located in the eastern foothills of the Sierra Madre Occidental, about 800 km northwest of Mexico City and 80 km north of the Fresnillo District. A series of quartz and calcite veins up to 7 km long and 10 m thick are hosted by a folded sequence of Cretaceous greywackes and shales which are crosscut and overlain by rhyolitic dikes and flows. The sedimentary host rocks are intensely altered and silicified. Ore grades are low at 165 g/t Ag and 0-1.92 g/t Au. In order to determine the hydrothermal level of the veins as now exposed, the ore and gangue mineralogy, alteration assemblage and fluid inclusion characteristics were determined. The Ag is mostly contained in pyragyrite; pyrite, galena, sphalerite and chalcopyrite are minor sulfide phases. Veins with dominant quartz gangue are mineralized, while the largest vein in the district, the Cazaderos vein, with dominant calcite gangue, is barren at the equivalent elevation, indicating a vigorous late-stage, barren pulse of hydrothermal activity. XRD and petrographic studies of fresh and altered rock show a compositional shift from the fresh graywacke assemblage quartz-calcite-dolomite-feldspar-chlorite-chlorite/smectite-smectite and poorly crystallized illite to an alteration assemblage of well-crystallized illite, kaolinite, and discrete montmorillonite with an increase in SiO_2 from non-altered to most intensely altered rock by 30%. Fluid inclusions homogenize between

160 and 370°C and have salinities ranging from 1.3 wt. % NaCl eq. in the southeast to 5.0 wt. % Nacl eq. in the northwest. The degree and completeness of argillic alteration, and the low hydrothermal T both lead to the interpretation that only the uppermost levels of mineralization are exposed on the surface, and that there is good potential for additional ore at depth, particularly in the quartz-dominated veins. (Authors' abstract)

ROBINSON, A.G., WALTON, J.R. and WILLIAMS, K.P.J., 1988, Raman and Fourier transform infrared spectroscopies for the analysis of fluid inclusions in mineral cements in sediments: Applications to petroleum exploration (abst.): Eleventh Int'l. Conf. on Raman Spectroscopy, Clark, R.J.H. and Long, D.A., eds., 5-9 Sept. 1988, London, England, Publ. John Wiley & Sons, New York, p. 1013-1014. Authors at British Petroleum Res. Centre, Chertsey Rd., Sunbury-on-Thames, Middlesex, TW16 7LN, UK.

Small inclusions (<~10 μm) were studied by Raman between 1200 and 3200 cm^{-1} for gases. Inclusions with a triple point of -98°C (14° lower than pure H_2S) were found to be H_2S plus N_2 and CH_4. FTIR measurements were also made on 10 μm oil inclusions in anhydrite; difference spectra showed aliphatic compounds and H_2O. (E.R.)

ROBINSON, G.R., Jr., HEMLEY, J.J. and CYGAN, G.L., 1988, Fe, Pb, and Zn ratios in sulfide-saturated chloride-dominated hydrothermal fluids (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 69. Authors at U.S.G.S., Reston, VA 22092.

Fe, Pb, and Zn ratios in pH-buffered 1 m total chloride solutions saturated with pyrite (py), pyrrhotite (po), magnetite (mag), galena (gn), and sphalerite (sp) over a range of 300-600°C and 0.5-2 kilobars (unpub. data and Hemley and others, 1986, Geology, v. 14, p. 377-379), vary consistently with T and are independent of P. The ratios are independent of limited variation in pH between two different alkali feldspar + muscovite + quartz buffers and are independent of pH variation caused by P change. This independence contrasts with the strong effect of P and pH on individual metal solubilities. Regression of the log molal metal ratio obeys a linear relationship with reciprocal T (given below) within the ±16% uncertainty envelope for Fe, Pb, and Zn measurement. Total metal concentrations in the fluid are buffered by the po-py-mag assemblage at any fixed total Cl^-; total molal Fe + Pb + Zn concentrations appear to be identical to molal Fe concentrations in the iron-only system under similar conditions, indicating that these metals compete principally with Fe^{+2} for Cl^-. The metal ratios can be described as exchange equilibria between metal monosulfides and metal concentrations in the fluid. Fe/Zn, Fe/Pb, and Pb/Zn ratios increase with decreasing T. These trends are consistent with typical metal zoning patterns in many base metal deposits. (Authors' abstract)

$$\mathrm{Log}\ (\mathrm{Fe/Pb}) = 967\ (\pm 118)/T\ (K) - 0.448\ (\pm 0.084)$$
$$\mathrm{Log}\ (\mathrm{Fe/Zn}) = 1083\ (\pm 76)/T\ (K) - 1.016\ (\pm 0.064)$$
$$\mathrm{Log}\ (\mathrm{Pb/Zn}) = 116\ (\pm 108)/T\ (K) - 0.528\ (\pm 0.077)$$

ROBINSON, G.R., Jr. and WOODRUFF, L.G., 1988, Characteristics of base-metal and barite vein deposits associated with rift basins, with examples from some early Mesozoic basins of eastern North America: U.S. Geol. Survey Bull. 1776, p. 377-390.

Fluid inclusion data for sphalerite and quartz, and sulfur isotope fractionation between coexisting galena and sphalerite indicate that the veins crystallized in the range of 100 to 250°C. The source fluids are inferred to have been brines of moderate salinity (10 to 16 eq. wt. % NaCl). (From the authors' abstract by E.R.)

RODDY, M.S., REYNOLDS, S.J., SMITH, B.M. and RUIZ, Joaquin, 1988, K-metasomatism and detachment-related mineralization, Harcuvar Mountains, Arizona: Geol. Soc. Am. Bull., v. 100, p. 1627-1639. First author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

The Bullard detachment fault, a regional low-angle normal fault exposed in the Harcuvar Mountains of west-central Arizona, separates lower-plate mylonitic rocks and chloritic breccia from upper-plate volcanic and sedimentary rocks. Areally extensive K-metasomatism has converted upper-plate mafic flows and felsic ash-flow tuffs into rocks with 8 to 12 wt. % K_2O, <0.4 wt. % Na_2O, and a simple K-feldspar-hematite-quartz mineralogy. The secondary K-feldspar is very pure (Or 95 to 99.5), monoclinic, and structurally similar to orthoclase. Differences in $\delta^{18}O$ values between secondary K-feldspar replacing sanidine phenocrysts (9‰ to 11‰) and K-feldspar replacing groundmass (11‰ to 14‰) in the tuffs imply differential O-exchange with migrating fluids. Whole-rock $\delta^{18}O$ values for tuffs (10‰ to 14‰) and mafic flows (6‰ to 9‰) do not, therefore, represent primary igneous values. The rocks apparently became K-metasomatized and ^{18}O-enriched while interacting with low- to moderate-T, neutral to alkaline, oxidizing brines that accumulated in an extensional basin above the detachment fault.

Cu-Au-Ag mineralization is concentrated in faults and fissures in metasomatized mafic flows above the detachment fault. Fluid inclusion studies show that mineralizing fluids had minimum T of 290 to 330°C along the detachment fault, 240 to 290°C in mafic flows above the detachment fault, and 100 to 130°C in barite-calcite-Mn-oxide veins farther from the detachment fault. The predominant mineralizing fluids near the detachment fault and in the mafic flows were saline brines with 13 to 17 eq. wt. % NaCl. More dilute brines with 6 to 12 eq. wt. % NaCl formed the barite-calcite-Mn-oxide veins. Inferred $\delta^{18}O$ values of the mineralizing fluids range from +3‰ for high-T quartz-sulfide veins to -5‰ for lower-T barite-calcite-Mn-oxide veins. The high salinities, oxygen isotope compositions, and geologic setting indicate that the mineralizing fluids were basinal brines. The mineralizing fluids apparently evolved from early deep-level, reducing basin brines to a later stage marked by the influx of higher-level oxidizing basin brines. Relatively minor amounts of less evolved, lower-^{18}O meteoric water entered the system during the very late stages of mineralization.

Paragenetic relations and geochemical and isotopic data indicate that mineralization was superimposed on previously K-metasomatized rocks. Mineralization and K-metasomatism may be indirectly linked, however, because both occurred during detachment faulting and both involved basinal brines. Specifically, K-metasomatism of upper-plate units liberated elements, such as Cu, Pb, Zn, Mn, Sr, and Na, that were incorporated into the mineralizing basin brines. Multiple fluid regimes during detachment faulting are indicated, because basin-brine-dominated mineralization overprinted lower-plate mylonitic rocks and breccia that had probably previously equilibrated with igneous or metamorphic fluids at deeper levels of the detachment system. (Authors' abstract)

RODIONOV, A.Ya. and KONOVALOVA, T.I., 1988, The application of gas-transportation reaction to the crystallization of beryl: Trudy Inst. Geol. i Geofiz. (Novosibirsk), v. 708, p. 129-139 (in Russian).

Indexed under "Fluid Inclusions." (E.R.)

RODRIGUEZ-CLEMENTE, R., VEINTEMILLAS-VERDAGUER, S., RULL-PÉREZ, F. and SANGWALT, K., 1988, Crystal growth from boiling solutions: Prog. Crystal Growth & Charact., v. 17, p. 1-40. First author at Inst. Ciencia de Materiales, C.S.I.C., c/Marti i Franques s/n. 08028 Barcelona, Spain.

This paper reviews the present status of crystal growth from boiling solutions. The understanding of the peculiar characteristic of this technique: high rates of growth, restricted applicability to substances presenting complexing phenomena in solution, high crystal perfection, etc., makes interesting the analysis of the structure of saturated solutions and the nature of crystal growth units. After a discussion of the role of complex formation and solute association, metastable zone width, crystal solution interface and bubbling in boiling solutions in applying this technique, the experimental set-ups reported so far are narrated. Finally, the macro and micromorphology, the growth kinetics and the perfection of the obtained crystals are described and discussed. (Authors' abstract)

ROEDDER, E. and HOWARD, K.W., 1988a Taolin Zn-Pb-fluorite deposit, People's Republic of China: An example of some problems in fluid inclusion research on mineral deposits: J. Geol. Soc., London, v. 145, p. 163-174.

This is the full paper for abstract in Fluid Inclusion Research, v. 19, p. 367-368. (E.R.)

ROEDDER, Edwin and HOWARD, K.W., 1988b Fluid inclusions in Salton Sea scientific drilling project core: Preliminary results: J. Geophy. Res., v. 93, no. B11, p. 13,159-13,164. First author at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA.

Fluid inclusions (191) in calcite, quartz, K-feldspar, and epidote from ≈1-mm veinlets in cores and well cuttings from 604-2560 m have Th from 217° to >500°C and vary widely in salinity, suggesting a complex history of fluids surrounding these samples. No dms were seen, and no clathrates were recognized on freezing. Vapor-rich inclusions under P, presumably containing CO_2 and/or CH_4, were found from a wide range of depths, suggesting that effervescence has occcurred. Low-salinity fluids (1.2-4.0 wt % NaCl eq) were present as deep as 1939 m. The data can be explained by a combination of processes such as thermal metamorphism of evaporites and other sediments and mixing of water from metamorphic dehydration reactions with partly evaporated Colorado River water. (Authors' abstract)

ROEDDER, Edwin and STALDER, H.A., 1988, "Pneumatolysis" and fluid-inclusion evidence for crystal growth from a vapor phase: Geol. Soc. India Memoir 11, p. 1-12. First author at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 01238, USA.

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 $g.cm^{-3}$. The best evidence for pneumatolytic conditions is found in the presence of vapor-rich fluid inclusions, but considerable ambiguity remains and hence such evidence must be used with care. Many samples formerly thought to be of pneumatolytic origin were most 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 Summit 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)

ROGERS, P.S.Z., DUFFY, C.J. and BENJAMIN, T.M., 1986, Advances in nuclear microprobe trace element analysis, *in* Microbeam Analysis-1986, A.D. Romig and W.F. Chambers, eds.: San Francisco Press, p. 157-163.

ROGERS, P.S.Z., DUFFY, C.J. and BENJAMIN, T.M., 1987, Accuracy of nuclear microprobe trace element analyses: Nuclear Instr. & Methods., v. B22, p. 133-137.

ROMBERGER, S.B., 1988, Mechanisms of ore deposition in solution breccias (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A139. Author at Dept. Geol. & Geol. Engrg., Colorado Sch. Mines, Golden, CO 80401.

The diversity in mineralogical and chemical composition of polymetallic ores occurring in collapse breccias suggests a complex set of geochemical processes are responsible for deposition. However, paragenetic studies indicate that the diversity is a result of the superposition of individual mineralizing events, each explained by simple physico-chemical changes occurring in the environment of deposition. Geothermometric studies indicate that deposition is not a result of T gradients. Lack of significant wall rock alteration suggests the solutions are close to chemical equilibrium with the host rocks, and in carbonate terranes this means changes in pH cannot be an important mechanism of deposition. Coarse-grained textures and deposit-wide rhythmic banding suggest subtle and episodic changes in solution parameters result in ore precipitation. The preferred mechanisms are changes in oxidation state and dilution as mixing occurs along an interface between two fluids of contrasting compositions. Base and ferrous metals transported as chloride complexes in saline solutions may be deposited as the latter mix with more dilute reduced solutions having higher sulfur activities. Uranium transported as uranyl complexes also will be precipitated as a result of reduction in similar geochemical environments. In contrast, precious metals will be transported as bisulfide complexes and precipitation is favored by oxidation, the latter most likely occurring as the reduced transporting solutions mix with more oxygenated waters. Paragenetic and episodic changes in mineralization may be the result of hydrologic changes at the site of deposition caused by variations in recharge rates for the two or more fluids involved. (Author's abstract)

RONA, P.A., 1988, Hydrothermal mineralization at oceanic ridges: Canadian Mineral., v. 26, p. 431-465. Author at National Oceanic & Atmosp. Admin., Atlantic Oceanographic & Meteor. Lab., 4301 Rickenbacker Causeway, Miami, FL 33149, USA.

A compilation of over 100 mineral occurrences at oceanic ridges and rifts comprising the global sea floor spreading center system has been made. The salinity of fluids from 29 locations, from the literature, is summarized in Table 6. (E.R.)

ROSE, A.W., KUEHN, C.A., SHENBERGER, D.S. and GAMMONS, C.H., 1988, Geochemistry and origin of hydrothermal fluids forming high Au/Ag, low base-metal gold deposits of Carlin, greenstone and related types (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 70. Authors at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802, USA.

Alteration assemblages at the Carlin deposit, Nevada, are zoned around fractured and permeable zones in the sequence (A) quartz + calcite + dolomite + illite + K-feldspar + pyrite (unaltered rock), (B) qtz + dol + ill + py ± cal, (C) qtz + dol + ill/Kmica + py, (D) qtz + dickite/kaolinite +

py ± Kmica, to (E) qtz + dick/kaol + py. Fluid inclusion and isotope data indicate that a deep fluid of 210 ± 25°C, low chloride (<0.2 m) high CO_2 (P = 500-800 bars), high H_2S, and a pH of 4.5 or less mixed with a cooler meteoric fluid in forming the deposit. Large amounts of carbonate were dissolved by carbonic acid to create increased porosity, leading to structural collapse. The high Au/Ag ratio and low base metals are explainable by high H_2S/Cl^-, leading to little Cl-complexing and low solubility of Ag, Zn, Pb and Cu sulfides, but significant concentrations of dissolved Au, as $AuHS^\circ$ or similar sulfide complexes.

Fluids of similar type (low Cl^-, high CO_2 and probably H_2S) are also indicated at the high Au/Ag, low base-metal, Au deposits of the Mother Lode-, greenstone- and Homestake-types, based on extensive carbonate alteration, and CO_2-rich but low Cl^- inclusions. These fluids can be formed during regional or contact metamorphism of impure pyritic carbonate rocks at T above about 300°C, given low-Cl^- water or a major fraction of water from metamorphic dehydration. They differ from conventional geothermal waters because of high CO_2, low Cl^-, and possibly higher T. (Authors' abstract)

ROSE, N.M. and BIRD, D.K., 1988, Metasomatic alteration of Tertiary dolerite dikes during continental rifting in East Greenland (abst.): EOS, v.68, p.468. First author at Dept. of Geo., Stanford Univ., Stanford, CA 94305.

Sheeted dikes and volcanic rocks near the East Greenland continental margin have been subjected to low-grade hydrothermal metamorphism. Within this region, zones of intense prehnite mineralization occur close to the centers and discontinuously along the lengths of certain dolerite dikes. Th of fluid inclusions in calcite overgrowths on prehnite suggest that prehnite alteration occurred above 315°C when P corrected for 4-6 km depth. Freezing point depressions indicate that the salinities of the hydrothermal solutions were between 2 to 3 eq wt % NaCl. These observations are consistent with the occurrence of prehnite+epidote+salite±actinolite in low salinity geothermal systems (e.g. Cerro Prieto and Iceland).

Prehnite mineralized dikes, like the epidosites formed in ophiolites, represent major vertical conduits for the flow of hydrothermal solutions. Their formation, during Tertiary continental rifting, requires a mechanism for channelizing and isolating large volumes of fluids under chemical conditions that favor Ca-Al silicate precipitation. (From the authors' abstract)

ROSE, S.C., PICKTHORN, W.J. and GOLDFARB, R.J., 1988, Gold mineralization by metamorphic fluids in the Chandalar district, southern Brooks Range -- Fluid inclusion and oxygen-isotopic evidence: U.S. Geol. Survey Circular C1016, p. 81-84.

The Au-quartz lodes were emplaced within the metasediments after peak metamorphism. Veins consist of both high-grade ribbon quartz, and low-grade to barren milky quartz. Vein mineralogy is consistent within all lodes. Quartz is the dominant gangue mineral with minor carbonate; the most abundant sulfide minerals are arsenopyrite, galena, stibnite, pyrite, pyrrhotite, and sphalerite. Au replaces galena, sphalerite, and arsenopyrite and also occurs as isolated grains in quartz.

P and(or) PS inclusions found in unstrained quartz were examined. P inclusions generally contain three phases at room T; CO_2 vapor, CO_2 liquid, and water. Some inclusions have only two phases at room T, CO_2 liquid, and water liquid, but generate a CO_2 vapor phase upon cooling a few degrees. The inclusions have consistent CO_2:H_2O volume ratios of 0.30 to 0.35. Similar relationships were observed in a limited number of fluid inclusions in sphalerite from the Mikado mine. The small range in Tm clathrate and Th CO_2 along with the consistent gas-to-liquid ratios for all the lodes indicate trapping of a one-phase fluid under similar P and T. There is no evidence of fluid immiscibility or boiling in these samples.

Tm CO_2 ranges from -56.6°C to -58.2°C. Tm clathrate ranged from 8.4°C to 10.8°C. Th CO_2 occurs between 22.8°C and 27.6°C. Th occurred between 265°C and 300°C.

Using relationships from Swanenburg (1980) and Burruss (1981), the bulk density and composition of the fluid inclusions can be estimated. Inclusions generally contain ~86 to 88 mole % H_2O, 12 to 14 mole % CO_2, 0.6-0.7 mole % CH_2*; < 3-3.5 mole % N_2, and < 3.0 wt.% NaCl. A minimum Pt of 75 MPa (750 bars) and a maximum Pt and Tt of 56 GPa (5.6 kbar) and 470°C were determined.

We believe that the isotopically heavy ore fluids are more likely derived from deep crustal sources. The isotope compositions and fluid inclusion compositions are similar to C-O-H fluids commonly observed in medium-grade metamorphic rocks. Such fluids are inferred to have been released during devolatilization reactions, and reflect compositions buffered by the surrounding mineral assemblages. Au is believed to have been mobilized from the pelitic metasediments by these metamorphic fluids. (From the authors' text by E.R.) * Sic

ROSE, W.I., GEIKEN, Grant, WOHLETZ, Kenneth, EPPLER, Dean, SUMNER, Barr, MILLER, Theresa, CHUAN, R.L., and SYMONDS, R.B., 1988, Direct rate measurements of eruption plumes at Augustine volcano: A problem of scaling and uncontrolled variables: J. Geophy. Res., v.93, n.B5, p.4485-4499. First author at Michigan Technological University, Houghton.

Discusses evolution of SO_2 & HCl (E.R.).

ROSELIEB, K., RAMMENSEE, W., BÜTTNER, H. and ROSENHAUER, M., 1988, Solubility and diffusion of rare gases in silicate melts (abst.): Terra cognita, v. 8, p. 75. Authors at Mineral.-Petrol. Inst. der Univ., Goldschmidtstr. 1, 3400 Göttingen, FRG.

The solubility and diffusion of rare gases (He, Ne, Ar, Kr) in albite melts has been determined. (E.R.)

ROSENBAUER, R.J., BISCHOFF, J.L. and ZIERENBERG, R.A., 1988, The laboratory albitization of mid-ocean ridge basalt: J.Geol., v. 96, p. 237-244. Authors at Br. Pacific Marine Geol., U.S. Geological Survey, Menlo Park, CA 94025.

Complete alteration of fresh mid-ocean ridge basalt to albite + actinolite + smectite took place in the presence of quartz and 3.4 m NaCl at 350°C and 400 bars. Significant Na-metasomatism occurred in exchange for Ca + Fe + Mn. In contast, alteration of the basalt/quartz mixture with a synthetically prepared "natural brine," and basalt with 3.4 m NaCl or "natural brine" did not produce significant albitization. Based on these and previous experiments that reacted basalt with a variety of fluids, it is concluded that excess silica, a high Na/Ca ratio, and an absence of strong acidity (dissolved Mg) in the altering fluid are important for the albitization of basalt. (Authors' abstract)

ROSENBAUM, J., RUBENSTONE, J., and ZINDLER, A., 1988, Relative abundances of LIL elements in fluid inclusions in mantle nodules (abst.): EOS, v.69, p.502. First author at Lamont-Doherty Geol. Obser. of Columbia Univ., Palisades, NY 10964.

In order to place limits on the relative abundance of LIL elements in mantle fluids, we have examined fluid inclusion-bearing minerals separated from spinel lherzolites from San Carlos, AZ; Potrillo Maar and Kilbourne Hole, NM; Nunivak, AK; and Salt Lake Crater, HI; and a wehrlite from Dreiser Weiher, FRG. Fluid inclusions in clinopyroxene (cpx) and olivine (ol) from these samples vary in morphology from single, isolated occurrences to planar aggregates; some contain a vapor bubble but no solid phases have been observed. Ol and cpx separates of inclusion-bearing and inclusion-free grains from each nodule were analyzed for K, Rb, Cs, Ba, Sm, Nd, Sr, U, Th, and Pb, by isotope dilution.

To a first order, Sm, Nd, and Sr contents of inclusion-bearing cpx are indistinguishable from those of cpx from the same nodule with no visible inclusions, although cpx from different nodules span a wide range of trace element concentrations and radiogeneic isotope compositions. In contrast, Ba, Rb, K, and Cs vary by up to factors of 2, 10, 100, and 1000, respectively, in inclusion-rich compared to inclusion-free cpx, with the greatest enrichments observed in a nodule from Nunivak. Initial data imply that Pb is also relatively enriched in fluid inclusions in both cpx and ol separates. (Authors' abstract)

ROSLYAKOVA, N.V., 1988, Gold behavior during ore formation: Bicentennial Gold 88, Abstracts, Geol. Soc. Australia, v. 23, no. 1-2, p. 469-471.

Indexed under "Fluid Inclusions." (E.R.)

ROSLYAKOVA, N.V., SHCHERBAKOV, Yu.G., BORTNIKOVA, S.B., RADOSTEVA, N.Ye., TSIMBALIST, V.G. and SHUGUROVA, N.A., 1987, Geochemistry of the formation of gold-ore deposits: Geochem. Int'l., 1988, v. 25, no. 4, p. 94-103. (Translation of full paper abstracted in Fluid Inclusion Research, v. 20, p. 331.) Authors at Inst. Geol. & Geophys., Siberian Div., Acad. Sci. USSR, Novosibirsk, USSR.

Measurements have been made on the Au, Ag, Pb, Zn, Cu, and rare-earth distributions in rocks and ores at Au deposits. The relative-concentration coefficients have been determined, along with the Au contents in [fluid] inclusion solutions, the Au distribution in metasomatites, and the carbon, oxygen, and suflur isotope compositions. Data on the association of the mineralization with rocks having elevated Au backgrounds are also used, from which it is concluded that the material in these deposits is mixed in origin: the volatile components have been derived from a plutonic source, while the metals and silica derive from a crustal one. Repeated alteration has been involved in producing the richest ores, with prolonged interaction between transmagmatic fluids and rocks enriched in Au. (Authors' abstract)

ROVETTA, M.R., 1988, Fracture in the mantle: The stability of cracks containing CO_2 (abst.): EOS, v.69, p.481.

ROWAN, E.L., 1987, Homogenization temperatures and salinities of fluid inclusions from the Viburnum Trend, southeast Missouri, and northern Arkansas zinc district: USGS Open File Rept. OF 87-0675, 26 pp.

Measurements have been made on fluid inclusions from mines and drill core within and adjacent to the Viburnum Trend and northern Arkansas zinc Mississippi Valley-type districts. Hydrothermal dolomite is the primary host mineral for the inclusions examined, but measurements have also been made on inclusions in sphalerite and calcite.

Measurements of Th and Tm ice for 306 fluid inclusions are tabulated and briefly discussed.

Results of this study give information on T and salinity of the ore fluids beyond the boundaries of the mining districts and provide insight into the regional distribution of the hot, saline brines trapped in the inclusions. (Author's abstract)

ROXBURGH, I.S., ed., 1987, Geology of high-level nuclear waste disposal: An introduction: Chapman & Hall, London, England, 229 pp.

Discusses the suitability of evaporites as HLW repositories and the relevance of fluid inclusion studies to such sitings. Concludes that the presence of fluid inclusions in otherwise stable evaporites, notably halite, can cause problems above 250°C. The author, therefore, suggests an upper design temperature limit between 150 and 200°C for evaporite repositories. (H.E.B.)

ROZANSKI, K., 1988, Deuterium content of fluid inclusions in carbonate cave deposits - Possible links to climate changes (abst.): Chem. Geol., v. 70, p. 169. Author at Isotope Hydrology Sec., Int'l. Atomic Energy Agency, Vienna.

Carbonate cave deposits, often called "speleothems," represent a potentially important source of information about past climatic fluctuations over continental areas. Fluid inclusions trapped in speleothems can be thought of as samples of palaeoinfiltration waters present in a cave during speleothem growth. It appears that deuterium isotopic composition of these waters is preserved in fluid inclusions which further allows reconstruction of past levels of D content in precipitation. From ^{18}O content of the speleothem calcite and D content of the fluid inclusions, the T of the formation of the given speleothem layer can be estimated.

Combined isotopic studies of speleothem samples originating from caves in Western and Central Europe allowed some important conclusions to be formulated regarding climatic and environmental conditions prevailing over this part of the European continent during the last 300,000 years:

a) δD values of fluid inclusions suggest a remarkable constancy of the heavy isotope content of European paleoinfiltration waters recharged during interglacial periods;

b) climate-induced, long-term changes in isotopic composition of precipitation and surface air T over Europe can be characterized by the D gradient of about 1.8‰ per °C;

c) an apparent constancy of the continental gradient in the D content of European palaeoinfiltration waters, as judged from fluid inclusion data, and its similarity to the present-day gradient suggest that atmospheric circulation over Europe has not undergone substantial changes during the last 300,000 years. (Author's abstract)

ROZANSKI, K. and DULINSKI, M., 1988, Deuterium and oxygen-18 content of fluid inclusions trapped in carbonate cave deposits: Freiberg. Forschungsh. C, v. C420, p. 92-105 (in English).

See previous item. (E.R.)

RUAYA, J.R., 1988, Estimation of instability constants of metal chloride complexes in hydrothermal solutions up to 300°C: Geochimica Cosmo. Acta, v. 52, p. 1983-1996.

RUB, A.K., KHETCHIKOV, L.N., KOTEL'NIKOVA, Z.A. and RUB, M.G., 1988, Inclusions of mineral-forming media in quartz from the Precambrian tin-bearing granitoids of the Northern Ladoga region and Mesozoic granitoids of the Soviet Far East, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 45-53 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 345-346. (E.R.)

RUBIN, J.N. and KYLE, J.R., 1988, Mineralogy and geochemistry of the San

Martin skarn deposit, Zacatecas, Mexico: Econ. Geol., v. 83, p. 1782-1801. First author at Bureau of Econ. Geol., The Univ. Texas at Austin, Univ. Station, Box X, Austin, TX 78713-7508.

The San Martin skarn [Cu-Zn-Pb-Ag±Au] deposit was formed by a hydrothermal system associated with intrusion of the 46-m.y.-old Cerro de la Gloria quartz monzonite stock into the middle Cretaceous Cuesta del Cura limestone. Andraditic grandite garnet and hedenbergitic clinopyroxene are the dominant prograde calc-silicate minerals; tremolite-actinolite appears to be present as both a prograde and a retrograde phase. Other retrograde phases include wollastonite, vesuvianite, epidote, and chlorite; fluorite and calcite are common, and minor quartz is also present. The metallic mineral assemblage is diverse and the paragenetic sequence can be divided into early, intermediate, and late stages.

Deposition of grandite garnet probably was initiated by an increase in fO_2 (and possibly a decrease in fS_2) and took place at T estimated in the range of 500° to 550°C. Garnet then became unstable relative to clinopyroxene and later calc-silicate alteration products. Fluid inclusion evidence suggests initially highly saline fluids (at least 24 wt % KCl and 36 wt % NaCl) with T of major sulfide deposition starting at about 425°C and declining thereafter. Initial values for fO_2 and fS_2 were such that metals were able to be transported as chloride complexes and sulfur was carried mainly as SO_2. Sulfide precipitation was probably caused by a continuing decrease in T and an increase in pH brought about by dissolution of $CaCO_3$. Values for $X(CO_2)$ in the hydrothermal fluids were low (≤ 0.05) throughout calc-silicate metasomatism and sulfide deposition. Relative metal solubilities were the major control on metal zonation. The Cu-Ag association is a product of thermal collapse of the mineralizing system, resulting in low-T mineral assemblages coexisting in high-T assemblages near the intrusive contact. (From the authors' abstract by E.R.)

RUDASHEVSKIY, N.S. and MALICH, K.N., 1988, Melt silicate-oxide-iron inclusions from dunites of the Konder alkaline-ultrabasic massif: Dokl. Akad. Nauk SSSR, v. 298, no. 5, p. 1198-1203 (in Russian). Authors at All-Union Sci.-Research Geol. Inst., Leningrad, USSR.

The studied inclusions (mostly in olivine) are spherical or hemispherical "droplets" from a few μm to 2-3 mm in size. Type 1 consists of a native iron inner core (with 0.03-0.26 wt.% Cr, 0.03-0.23 wt.% Ni, 0.04-0.20 wt.% Cu) and a chrome wüstite outer core (up to 2 wt.% Cr_2O_3). Wüstite segregations may also be found inside the iron inner core. Type II consists of an aggregate of silicate (olivine or glass), iron and wüstite. Electron microprobe analyses of the inclusion components are given. Glass has compositions close to various minerals: pyroxene, acid plagioclase and K-spar. Moreover crystals of diopside-hedenbergite, grossular-andradite, spinels and quartz were found. On the basis of the phase diagram of the inclusion components one may determine the upper T range of formation as 1533°C and their origin should be connected with quick cooling of magma in presence of reducing fluids. (A.K.)

RUIZ, Joaquin, PATCHETT, P.J. and RICHARDSON, C.K., 1988, Sr isotopes and the source of fluorite-mineralizing solutions in the Cave-in-Rock district, U.S.A. (abst.): Chem. Geol., v. 70, p. 137. Authors at Dept. Geol. Sci., Univ. Arizona, Tucson, AZ 85721.

The Cave-in-Rock district has been a leading fluorite producer in the United States for most of the century. Fluorite-calcite-galena-sphalerite and barite occur in numerous vein, breccia and stratiform deposits in the southern part of the Illinois basin. The fluorite district occurs in a Paleozoic sequence of shelf-type sedimentary rocks. The ore horizons are in Upper Mississippian rocks and consist mostly of oolitic and fossiliferous light grey limestones of the Ste. Genevieve and Renault Formations. Dikes of mica peridotite and diatremes approximately 270 Ma in age intrude the Paleozoic sequence. Central to understanding the genesis of these deposits are the age of deposition of the ore and the source of the ore components. Previous studies have defined the paragenetic relationships of finely banded fluorite and correlated fluorite bands between mines. The Sr isotopic values for all the hydrothermal minerals in the district fall in a narrow range between 0.70927 and 0.71025. There is a small but significant shift in the isotopic composition of the minerals toward less radiogenic values with time. These isotopic data show that there were two important sources of Sr for the fluorite: an early radiogenic component and later Sr which is in isotopic equilibrium with mineralized host rocks. The more radiogenic component is similar to that of basinal brines that formed Mississippi Valley type mineralization in the midcontinental U.S. This interpretation is supported by fluid inclusion data. Comparing the Sr isotopic composition of the mineralization with that of the alkalic rocks in the district, which could have supplied F and Sr to the brines, suggests that the as yet undetermined age of the Cave-in-Rock mineralization was approximately 200 Ma. (Authors' abstract)

RUMBLE, D., 1988, Fluid flow during regional metamorphism (abst.): EOS, v.69, p.464.

RUMYANTSEV, V.N., GANEEV, I.G. and RUDNEV, V.V., 1988, The cause of the pulsation change in temperatures of homogenization of inclusions during veined mineral-formation, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 56-59 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 348-349. (E.R.)

RUNNELLS, D.D., KEMPTON, J.H. and LINDBERG, R.D., 1988, Problems in the interpretation of redox chemistry in geochemical modeling of natural waters (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated).

RUTHERFORD, M.J. and DEVINE, J.D., 1988, The May 18, 1980, eruption of Mount St. Helens; 3, Stability and chemistry of amphibole in the magma chamber: J. Geophys. Res., Part B, v. 93, no. 10, p. 11,949-11,959.

Indexed under "Fluid Inclusions." (E.R.)

RUVALCABA-RUIZ, D.C. and THOMPSON, T.B., 1988, Ore deposits at the Fresnillo mine, Zacatecas, Mexico: Econ. Geol., v. 83, p. 1583-1596. First author at Pasaje E No. 405, Fraccionamiento Industrial Aviacion, San Luis Potosi 78140, Mexico.

The Fresnillo mine ore deposits consist of replacement chimney and manto bodies, disseminated sulfide bodies, and vein deposits hosted mainly in Cretaceous marine sedimentary and volcanic rocks. The base metal-Ag deposits are zoned to the southeast away from a small quartz monzonite stock, with increasing Ag content and decreasing base metal values with distance from the stock. Wall rocks adjacent to the stock exhibit silicification and calc-silicate alteration that has been partially replaced by the sulfide minerals. Vein wall rocks exhibit potassic, phyllic, argillic, and propylitic alteration with increasing distance from the veins.

Fluid inclusions in quartz, calcite, and sphalerite contain two phases, water and water vapor, and are dilute (0-12 eq wt % NaCl) solutions. Filling T and salinities vary sharply between growth zones in ore and gangue minerals with distinct salinity increases in sphalerite. Filling T in chimney, manto, and deep vein quartz and calcite range between 240° and 350°C while shallow and distal quartz, calcite, and sphalerite from veins yield T between 140° and 275°C. Sphalerite geobarometry of samples from the Dueva Santa manto yield a total P of 730 bars. P correction for the fluid inclusion filling T from samples in chimney and manto deposits is 70°C. Ag-rich veins formed from fluids that were boiling, indicating a depth of formation of 350 m below the paleosurface.

Sulfur isotope analyses of galena and sphalerite form chimney, manto, and vein deposits exhibit overlapping ranges of values, with galena depleted in ^{34}S with respect to sphalerite. The calculated $\delta^{34}S_{\Sigma s}$ utilizing fluid inclusion filling T is -3.0 ± 0.4 per mil. Such a composition may have been derived from a slight shift in ore fluid pH (as indicated by the wall-rock alteration assemblages) or by increased log fO_2 (as indicated by minor hematite and amethystine quartz) from an original $\delta^{34}S_{\Sigma s}$ of 0 per mil. Galena Pb isotope data indicate that mantos and veins formed from the same deep crustal source.

The fluctuating T and salinity values from growth zones in ore and gangue minerals, deep crustal source of the Pb, and magmatic origin of the sulfur argue for a mineralizing system that derived its fluids from magmatic and meteoric sources. The magmatic fluids associated with the quartz monzonite stock spread upward and outward along major regional faults and bedding planes of the sedimentary rocks, mixing and cooling with meteoric fluids. The ore and gangue minerals may have been precipitated due to mixing of these two fluids. Boiling of ore fluids may have caused ore mineral precipitation in the Ag-rich veins as suggested by sharp vertical increase in Ag concentration at the 350 m (below the present surface) level. (From the authors' abstract by E.R.)

RUXTON, P.A. and PLUMMER, G., 1984, Economic geology and fluid inclusion history of the Scamander mineral field and Great Pyramid tin deposit N.E. Tasmania (abst.): Mineral Exploration & Tectonic Processes in Tasmania, Abst. Vol. & Excursion Guide, Burnie, Nov. 1984, Geol. Soc, Australia, p. 45-47. Authors at Billiton Australian & LaTrobe Univ., Melbourne.

An earlier but more detailed version of material covered in abstract in Fluid Inclusion Research, v. 19, p. 376. (E.R.)

RYDER, Graham, 1988, Impact splashing and quenching during crystallization of volcanic Apollo 15 KREEP basalts: Papers 51st Ann. Meeting Meteoritical Soc., LPI Contrib. 665, 1988, p. H-4.

Indexed under "Fluid Inclusions." (E.R.)

SAFRANOV, T.A., GRISHINA, S.N., LUCHNIKOV, V.S. and KUTOLINA, G.V., 1986, Temperatures of maximum heating of salt in Upper Jurassic halide formations of southeastern Central Asia, in A.L. Yanshin and G.A. Merzlyakov, eds., Physicochemical mechanisms of sedimentation in saline basins: Izd. Nauk, p. 34-37 (in Russian).

SAHAGIAN, D.L. and ANDERSON, A.T., 1988, Vesicle distribution in basalt flows: A new tool for the determination of paleoelevation and atmospheric pressure (abst.): EOS, v.69, p.514.

SAIGAL, G.C. and BJØRLYKKE, K., 1987, Carbonate cements in clastic reservoir rocks from offshore Norway - relationships between isotopic composition, textural development and burial depth, in Marshall, J.D., ed., Diagenesis of sedimentary sequences: Geol. Soc. Spec. Publ. No. 36, p. 313-324. (Continued)

Many Jurassic and Lower Cretaceous sandstone reservoir rocks from offshore Norway contain carbonate-cemented intervals which typically make up 1-10% of the total sequence. Being nearly impermeable to fluid flow, their distribution may strongly influence reservoir properties. It is therefore important to understand the genesis of these carbonate cements. Studies of the Jurassic and Lower Cretaceous reservoir rocks from the Haltenbanken and Viking Graben area show that the sandstones contain dominantly two types of calcite cements: (i) microsparry and sparry calcite (Type I) and (ii) poikilotopic calcite (Type II). Type I calcite with $\delta^{18}O$ values between -4.5 and -8.4‰ PDB precipitated relatively rapidly at shallow burial and at T between 15 and 40°C, possibly from porewater of meteoric origin. Type II calcite with $\delta^{18}O$ values between -10 and -12‰ PDB have precipitated later at T corresponding to 50-60°C (at ~1.5 km burial depth). Fluid inclusion data also indicate that Type II calcites have crystallized at T between 56 and 68°C. Silicate grains are often corroded by Type I calcite while grains contained in Type II calcite are uncorroded, suggesting that the porewater was in near equilibrium with the main silicate phases (quartz and feldspar) during the precipitation of Type II calcite. The degree of supersaturation in the porewater with respect to low Mg calcite probably decreased with increasing burial depth as sources of more soluble carbonate (aragonite, high Mg calcite) were exhausted, causing slower precipitation rates and increased crystal size. The Type II (poikilotopic) calcite is thought to have formed at the expense of only slightly more soluble low Mg calcite crystals. The fact that the Type II calcite shows nearly the same $\delta^{18}O$ value (-10 to -12‰ PDB) in sandstones ranging in present burial depth from 1.6 to 5 km suggests that this type of carbonate cementation probably took place early (at T less than 60-70°C), and that very little dissolution and reprecipitation occurred at higher T (greater burial depth). (Authors' abstract)

SALEMINK, J. and SCHUILING, R.D., 1987, A two-stage, transient heat and mass transfer model for the granodiorite intrusion at Seriphos, Greece, and the associated formation of contact metasomatic skarn and Fe-ore deposits, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 547-575. Author at Inst. Earth Sci., Univ. Utrecht, P.O. Box 80021, 3508 TA Utrecht, The Netherlands.

At Seriphos, Cyclades, Greece, the shallow intrusion of a granodiorite pluton produced a contact metamorphic aureole and extensive contact metasomatic skarn and Fe-ore deposits. Based on geological evidence a simplified, one-dimensional, two-stage mathematical model is developed describing the coupled transfer of heat and mass during the thermal evolution of the intrusive system.

By using model parameters obtained from experimental data as well as from observed mineral assemblages, oxygen isotope results and fluid inclusion studies, sufficient information is obtained to construct a model that agrees well with the field evidence. The total amount of Fe that can be modelled to precipitate in the skarn and Fe-ore deposits is well in accordance with the field estimations. (From the authors' abstract by E.R.)

SALVI, Stefano and WILLIAM-JONES, A.E., 1988, A preliminary fluid inclusion study of the Strange Lake Zr, Y, REE deposit, Labrador-Quebec (abst.): GAC/MAC Program with Abstracts, v.13, p.A108. Authors at Dept. of Geol. Sci., McGill Univ., Montreal, Quebec H3A 2A7.

The Strange Lake alkalic complex intrudes rocks of the Churchill Province on the Labrador-Quebec border, 150 km west of Nain. The potential economic mineralization consists of up to 20% Zr, Y, Nb, Ta, and REE in a variety of exotic minerals such as elpidite, gittinsite, and narsarsukite. Pseudomorphic replacement of primary alkali silicate minerals by Ca-bearing phases is a common feature of the deposit. For example, the Na-Zr-silicate elpidite is commonly replaced by the Ca- Zr-silicate gittinsite plus quartz; titanite and quartz form pseudomorphs after the Na-Ti-silicate, narsarsukite. The original shapes of the pseudomorphed grains are in part defined by trains of fluid inclusions. This is evidence for a primary origin of the inclusions in the replacing phases. A reconnaissance study indicates the existence of at least three major types of fluid inclusions: two-phase, liquid-rich aqueous inclusions; two-phase, vapor-rich inclusions; and three-phase CO_2-bearing inclusions indicates Th of 120° to 372°C; Te range between-43° and -23°C, and Tm ice between -16 and -4°C. Fluid inclusion data (low Te), together with the Ca enrichment trend shown by the mineralogy, suggest that a relatively low T, Ca-bearing mineralizing fluid may have played an important role in the formation of the Strange Lake Deposit. (Authors' abstract)

SAMOILOV, V.S., KOVALENKO, V.I., NAUMOV, V.B., SANDIMIROVA, G.P. and CHUVASHOVA, L.A., 1988, Immiscibility of silicate and salt melts during the formation of the Mushugai-Huduk alkaline complex (southern Mongolia): Geokhimiya, no. 10, 1988, p. 1447-1459 (in Russian) (see Translations).

SAMSON, I.M. and BANKS, D.A., 1988, Epithermal base-metal vein mineralization in the Southern Uplands of Scotland: Nature and origin of the fluids: Mineral. Deposita, v. 23, p. 1-8. First author at Dept. Geol., Univ. Windsor, Windsor, Ontario, Canada, N9B 3P4.

The sedimentary sequences of the Southern Uplands of Scotland host numerous lead-zinc-copper-silver vein deposits, the genesis of which has never been adequately explained. Fluid inclusion and stable isotope analysis of vein minerals from these deposits indicate that, for the vein stages studied, the mineralizing fluids were low T (< ~150°C), high salinity (~19 to 30 equiv. wt. % $NaCl + CaCl_2$) modified meteoric waters. A consideration of the availability of such fluids throughout the geological history of the Southern Upland suggests a Lower Carboniferous (Dinantian) age for the mineralization. (Authors' abstract)

SAMSON, I.M. and WILLIAMS-JONES, A.E., 1988, Fluid compositions associated with syn-contact metamorphic copper mineralization, Mine Madeleine, Quebec, Canada (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A282. First author at Geol. Dept., Univ. Windsor, Windsor, Ontario, Canada N9B 3P4.

At Mine Madeleine, Quebec, pre- to syn-metamorphic chalcopyrite-bornite-pyrrhotite-quartz veins occur in a biotite-cordierite hornfels in the contact aureole of the Devonian, felsic McGerrigle pluton. The intruded sequence comprises dominantly Cambro-Ordovician shales, greywackes and carbonates.

Quartz-hosted fluid inclusion compositions are highly variable and include very low to very high salinity aqueous, aqueous-free volatile, and mixed aqueous-volatile types.

Raman spectroscopy reveals that these fluids have highly variable concentrations of CO_2, CH_4, and N_2; $XH_2O = 0$ to 1; $XCO_2 = 0$ to 0.9; $XCH_4 = 0$ to 1; and $XN_2 = 0$ to 0.77. The highest XCO_2 values are found in mixed aqueous-volatile fluids; whereas CH_4-N_2-rich fluids are aqueous free. The large ranges in fluid composition are interpreted to represent metamorphic devolatilization of a variety of rocks: CO_2 from carbonates; CH_4 and N_2

from pelites; along with a variable input from orthomagmatic, aqueous fluids. The nitrogen may have originated in bitumens in the pelites or as fixed NH_4^+ in phyllosilicates and cordierite. The low XH_2O of CH_4-N_2-rich fluid inclusions reflects the large immiscibility gap in this system compared to that in CO_2-rich systems. (Authors' abstract)

SANDER, M.V., 1988, Epithermal gold-silver mineralization, wall-rock alteration, and geochemical evolution of hydrothermal fluids in the ash-flow at Round Mountain, Nevada: PhD dissertation, Stanford Univ., Stanford, CA, USA, 309 pp.

Indexed under "Fluid Inclusions." (E.R.)

SANDER, M.V. and BLACK, J.E., 1988, Crystallization and recrystallization of growth-zoned vein quartz crystals from epithermal systems - Implications for fluid inclusion studies: Econ. Geol., v. 83, p. 1052-1060. First author at Echo Bay Exploration, 5250 Neil Road, Suite 300, Reno, NV 89502.

One criterion commonly used for recognizing the P origin of fluid inclusions is the occurrence of inclusions within a single concentric "growth" zone of the host crystal. In this communication, alternative interpretations of concentric fluid-rich zones in coarse-grained quartz from epithermal systems are presented. We suggest that some such zones were originally deposited as metastable, hydrous chalcedony or amorphous silica. Fluid inclusions contained within them were created during postdepositional recrystallization of the original host to quartz. We call such inclusions "pseudoprimary" to stress that the zones in which they are trapped reflect P depositional processes but that the inclusions themselves are products of recrystallization, [and] cannot provide reliable microthermometric information about the conditions of P silica deposition.

In other cases, micrometer- to submicrometer-scale fluid inclusions were trapped along dislocations between adjacent aligned crystallites that constitute the host. The inclusions coalesced and matured as the dislocations healed. Depending on initial trapping conditions and variations in P and T during healing, the resulting large fluid inclusions amenable to microthermometry may not accurately reflect the P conditions either. (From the authors' text)

SANO, Yuji, NAKAMURA, Yuji, NOTSU, Kenji and WAKITA, Hiroshi, 1988, Influence of volcanic eruptions on helium isotope ratios in hydrothermal systems: Geochim. Cosmo. Acta, v. 52, p. 1305-1308. (Revised title, from correction on p. 2183, 1988.)

SANTARELLI, Frédéric, ALDERTON, David and GUY, Bernard, 1988, A fluid inclusion study on the tungsten skarns of Costabonne (Pyrénées): Some results on overall chemistry and daughter minerals: C.R. Acad. Sci. Paris, v. 307, p. 1231-1236 (in French; English summary). First author at Dept. Géol., Ecole des Mines, 158, cours Fauriel, 42023 Saint-Etienne Cedex 2, France.

We have analyzed the fluids contained in the quartz crystals within the skarns of Costabonne by flame spectrometry. The dms have been analyzed by scanning electron microprobe. The fluids are characterized by high Ca contents and moderate to low Mn, Mg and Zn contents. The fluids in transformed granites show correlated increases in Ca/Na and Mn/Na and decreases in K/Na in good agreement with the chemistry of the host rocks and revealing the opening of the system. Elements detected in the dms are Na, K, Ca, Mn, Cl, Si; the presence of Al is noticeable. These elements are combined as chlorides (NaCl, $CaCl_2$), carbonates (calcite) and silicates (micas). (Authors' abstract)

SANTOS, R.V., 1988, Geology and geochemistry of the fluorite deposit from Mato Preto carbonatitic alkaline complex, Paraná State (Brazil): M.S. thesis, Univ. Brasilia (in Portuguese). Author at Dept. Geosci., Univ. Brasilia, 70910, Brasilia, DF, Brazil.

The Mato Preto alkaline complex is composed by four main circular structures, each roughly 1 km in diameter. Three are located in the northern side of Mato Preto brook. They represent fenitized syenites as the dominant lithology and calcitic carbonatites, phonolites, and ultramafic alkaline rocks as subordinate ones. The fourth structure is located to the south of Mato Preto brook and is formed by phonolites and intrusive pipe breccias in which the matrix is a carbonatite of dolomite-ankeritic composition.

Concentrations of fluorite are known in almost all areas of the complex specially to the northern side of the Mato Preto brook. The Clugger deposit located in the NW corner of the complex is composed of four main lenses disposed subparallel to the Morro Agudo fault. The hydrothermal alteration zone in the deposit area is characterized by silicification and argillization of the host rocks.

Six main stages of fluorite generation have been identified. Among them the most important are the "colorless-microcrystalline" and the "purple" stages. The former occurs replacing the carbonatite carbonates or forming druses. It was precipitated after the purple fluorite.

The REE spectra are similar for the carbonatites and the two main types of fluorite. In the whole sequence of fluorite deposition these data also indicate a decrease in the total content of REE and an enrichment of the HREE in relation to the LREE.

The carbonatites of the Clugger deposit area are enriched in δC^{13} and δO^{18} in relation to the rest of the complex. This is probably a consequence of greater reactivity of the carbonate enriched in lighter isotopes with mineralizing fluids.

Fluid inclusions from the Mato Preto fluorites are two-phase, with low salinity. An exception to this is observed in the colorless-microcrystalline fluorite where empty or decrepitated inclusions are present. These suggest that a fluid with low boiling T (CO_2?) originally filled those cavities. (Author's abstract translated and abridged by K. Fuzikawa)

SANTOSH, M., ed., 1988a Fluid Inclusions: Geol. Soc. India Memoir 11, 158 pp.

This volume contains 13 papers, each of which is abstracted here. (E.R.)

SANTOSH, M., 1988b Granite-molybdenite system of Ambalavayal, Kerala: Part II. Nature of mineralization, sulphur isotopes, fluid characteristics and genetic model: J. Geol. Soc. India, v. 32, p. 191-213. Author at Center for Earth Sci. Studies, P.B. 7250, Akkulam, Trivandrum 695 031.

The alkali granite pluton of Ambalavayal in Wynad district, Kerala, carries an 800 m wide zone of disseminated molybdenite mineralization. Molybdenite also occurs as flakes and flaky aggregates in pegmatites and quartz veins. XRD and geochemical data indicate the molybdenite to be hexagonal $2H_1$ polytype. The general mineralogic and geochemical features of the granite are consonant with those of granite molybdenite systems in general. The sulphur isotope values in five molybdenite separates range from -1.62 to +1.54‰, denoting a narrow spread and a single igneous source. Fluid inclusions commonly occur in quartz associated with the granite, pegmatites and quartz veins. Heating-freezing studies show that the granite quartz entrapped high density (0.90-0.95 g/cm^3) CO_2-rich fluids at 4.5-5.2 Kb. Coexisting CO_2 and CO_2-H_2O inclusions in pegmatites yield a P-T estimate of 2.2 Kb and $500^{\circ}C$. Fluid inclusions in the mineralized quartz veins show that the ore-forming fluids (with a maximum salinity of 15 wt. % NaCl) were heterogeneous and the molybdenite precipitation was triggered by adiabatic decompression and 'boiling' at 340-360°C and vapor P of 110-150 bars. The cooling curve of the granite constructed from combined P-V-T data shows a T-convex path, implying near-isothermal upward movement of the granite magma. The data are consistent with a genetic model linking magmatism and metallogeny with extensional tectonics in the late Precambrian. (Author's abstract)

SANTOSH, M., 1988c Fluid inclusion palaeopressures and source of carbonic fluids in the massive charnockites of Kerala, South India: Geol. Soc. India Memoir 11, p. 91-99. Author at Centre for Earth Sci. Studies, Akkulum, Trivandrum-695 010, India.

Massive charnockites, characterized by amphibole to orthopyroxene dehydration, constitute the vast high-grade segment bounded by Achankovil shear zone (AC) in the south and Palghat-Cauvery shear zone (PC) in the north. Fluid inclusion studies, the only effective tool for palaeopressure determination in this garnet-free terrain, reveal that nearly pure carbon dioxide with uniform densities was the ambient fluid species during peak metamorphism. The CO_2 equation of state barometer yields a narrow range of 5.0-5.8 kbar P for eight widely-spersed localities south of the PC, in continuum with the similar P estimates from the supracrustals south of AC. To the north of PC, however, both fluid inclusion and mineral equilibria record higher P, marking PC as a major tectonic boundary. Carbon isotope measurements of fluid inclusions in the massive charnockites have yielded $\delta^{13}C$ values in the range of -2 to -7.7‰, suggestive of a mantle source. The strong correlation of $\delta^{13}C$ values with fluid densities in these rocks, however, indicate the possibility of a devolatilizing deep crustal carbonate source for the CO_2. (Author's abstract)

SANTOSH, M. and DRURY, S.A., 1988, Alkali granites with Pan-African affinities from Kerala, S. India: J. Geol., v. 96, no. 5, p. 616-626.

Indexed under "Fluid Inclusions." (E.R.)

SANTOSH, M., HARI, K.R. and CHATTERJEE, A.C., 1988, Fluid inclusions in Deccan basalt: Geol. Soc. India Memoir 11, p. 37-43. First author at Centre for Earth Sci. Studies, P.B. 7250, Akkulam, Thuruvikkal P.O., Trivandrum 695 031, India.

Phenocryst minerals in the Deccan basalts show two principal categories of inclusions, namely, silicate-melt and CO_2. The silicate-melt inclusions contain devitrified glass, dxls, randomly trapped minerals and CO_2-rich vapor. The Th range between 900 and 1250°C. The coeval CO_2 inclusions have densities in the range of 0.50-0.65 g/cm^3. Entrapment estimates attribute P of 2.2-3.5 kbar and depths of 6-13 Km. Fluid inclusion characteristics denote that the phenocryst minerals in the Deccan traps crystallized from a silicate-melt in the presence of a supercritical CO_2 fluid. Both silicate-liquid and silicate versus sulfide-liquid immiscibilities in the melt are indicated. (Authors' abstract)

SANTOSH, M., JACKSON, D.H., MATTEY, D.P. and HARRIS, N.B.W., 1988a Characteristics and carbon isotopes of fluids in the southern Kerala granulites and their bearing on the source of CO_2 (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 133-135 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 159-161). First author at Centre for Earth Sci. Studies, P.B. 7250, Akkulam, Trivandrum 965 031, India.

Carbon dioxide-rich inclusions commonly occur in the banded charnockites and khondalites of southern Kerala as well as in the incipient charnockites formed by desiccation of gneisses along oriented zones. Comprehensive microthermometric measurements constrain their densities to be in the range of 0.95-1.0 g/cm^3 in banded charnockites, 0.87-0.97 g/cm^3 in khondalites and

0.83-0.95 g/cm^3 in incipient charnockites. The combined high density fluid inclusion isochores and the range of thermometric estimates from mineral assemblages indicate entrapment P in the range of 5.4 to 6.1 kbar.

The analytical results of stepped heating show that the banded charnockites and gneisses contain about 50-60 ppm carbon, whereas the incipient charnockites are characterized by more abundant (100-200 ppm) carbon. The carbon isotopic compositions range from -10‰ to -12‰ in banded charnockites and -8‰ to -10.3‰ in the gneisses.

Even though the apparent small shift in carbon isotope composition during charnockite formation is consistent with internal buffering, the observed carbon dioxide abundance in the incipient charnockites as compared to their precursor gneisses argues for external buffering of CO_2. This leads us to infer that even though some fluid flushing did occur, it equilibrated with graphite present in the rocks during charnockite formation. (From the authors' abstract by E.R.)

SANTOSH, M., JACKSON, D.H., MATTEY, D.P. and HARRIS, N.B.W., 1988b, Carbon stable isotopes of fluid inclusions in the granulites of southern Kerala: Implications for the source of CO_2: J. Geol. Soc. India, v. 32, p. 477-493. First author at Centre Earth Sci. Studies, P.B. 7250, Akkulam, Trivandrum 695 031.

Full paper for previous abstract. (E.R.)

SAO, A.M., 1988, Molybdenum deposit of Chita (San Juan province): Postmagmatic evolution of the granitic plutons: Asoc. Geol. Argentina, v. 42 (3-4), p. 349-361 (in Spanish; English abstract).

The postmagmatic evolution of the Chita granitic stock (Neopaleozoic magmatism in the Frontal Range of Argentina) was traced studying the fluid inclusions contained within crystals of beryl belonging to a Mo deposit closely associated with the magmatism. Thermometric data suggest that beryl crystals were precipitated at ~425°C from hydrothermal fluids evolving at that moment from supercritical into liquid, with a composition close to the H_2O-NaCl system (around 5% NaCl eq.), and at P near 360 bars (= 1.33 km). This P and depth may also be considered as the intrusion level of the pluton. (Author's abstract)

SARDA, Ph., STAUDACHER, Th. and ALLEGRE, C.J., 1988, Neon isotopes in the mantle (abst.): Chem. Geol., v. 70, p. 40. Authors at Lab. Geochimie & Cosmo., I.P.G., 4 Place Jussieu, 75252 Paris Cedex 05, France.

We report new neon isotopic data on a suite of submarine glasses from Mid Ocean Ridges (MORB) from various locations (Atlantic, Pacific, Indian), and from Loihi seamount, Hawaii (OIB). Most of the results are from the Reynolds-type mass spectrometer ARESIBO II where the gases were released by stepwise heating. Stepwise crushing in vacuo was also performed. Taking extreme care we have reduced the blank to as low as 1.5 10^{-11} cm^3 STP ^{20}Ne at 1000°C (15 mn). Other improvements, including measurement of the isotopic composition of blanks and backgrounds, lowered the uncertainty to acceptable levels: typically 1-2% (1 σ error) on the $^{20}Ne/^{22}Ne$ ratio from the 1000°C step for a 1 g MORB glass sample.

The isotopic composition of Ne from Loihi seamount is undistinguishable from air, which supports the close-to-atmospheric isotopic composition of the deep undegassed mantle for all the noble gases but helium. In MORB, $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$ ratios are highly correlated. This correlation passes through the composition for air, in the classical three isotopes plot (figure). We interpret this as evidence for mixing between a high 20/22 and 21/22 end-member (the mantle source for MORB), and an air-like end-member being a plume (mixing in the mantle). Contamination by sea water should be minimal because we used stepwise heating and crushing. Correlations with He, AR and Xe support this.

The occurrence of very high, solar-like ^{20}Ne/^{22}Ne ratios in the depleted mantle ("solar wind" ^{20}Ne/^{22}Ne = 13.7) is not readily accounted for by nuclear processes. We discuss two tentative hypotheses: transient nonequilibrated mass fractionation, and also injection of interplanetary dust particles into the upper mantle via subduction of sediment, based on recent neon isotope measurements of Pacific red clay sediments. (Authors' abstract)

SASADA, Masakatsu, 1988a. Microthermometry of fluid inclusions from the VC-1 core hole in Valles Caldera, New Mexico: J. of Geophy. Res., v.93, n.B6, p.6091-6096. Author at Geol. Survey of Japan, Tsukuba, Ibaraki.

Fluid inclusions in vein quartz and calcite from core samples of the VC-1 hole were studied with microscope heating/freezing and crushing stages. All samples originate from hydrothermally altered Paleozoic rocks predating formation of the Jemez Mountains volcanic field and Valles caldera. Most Th of the liquid-rich inclusions are above the present well T, but some Th of P inclusions from 515 m and those of S inclusions from 723 m fit the present well T curve measured 10 months after completion of the well. The maximum T recorded by the P inclusions is 275°C from hydrothermal quartz in the Sandia Formation at 811-m depth. The total range of Th for samples from several depths (90°C) indicates cooling from the maximum T. The salinity of fluid inclusions in hydrothermal quartz and calcite is generally low, <1 wt.% NaCl eq. High-salinity fluid, up to 5 wt.% NaCl eq, has been found in several calcite veins from the lower part of the Madera Limestone. The salinity decreases with decrease of Th of the S inclusions, and that with lowest Th at the lower part of the Madera Limestone is similar to those from the other depths. These data show that early hot water circulation system involved several types of fluid, whereas the later one was a homogeneous fluid. The salinity of fluid inclusions in detrital quartz (presumably inherited inclusions) is higher than that in hydrothermal minerals. Some of these inclusions show extraordinary low T of final melting point of ice (about -40°C), suggesting that a $CaCl_2$ component is present. CO_2 contents in fluid inclusions were estimated by the bubble behavior on crushing. Crushing results indicate that CO_2 content of the early fluid is ≥0.35 wt.%, and that of the later fluid is ≈0.2-0.3 wt.%. Geothermal fluid trapped in the fluid inclusions representing the present T regime is comparable in composition to those from the Baca geothermal field inside the caldera and to those from hot springs in San Diego Canyon. (Author's abstract)

SASADA, M., 1988b Homogenization temperatures of fluid inclusions versus borehole temperatures (abst.): Int'l. Symp. on Geothermal Energy, Kumamoto and Beppu, Japan, Nov. 10-14, 1988, p. 43. Author at Geol. Surv. of Japan, Higashi 1-1-3, Tsukuba 305, Japan.

Fluid inclusions in minerals have generally put several thermal episodes on record. Th of fluid inclusions trapped at the latest thermal event may indicate the present T of underground geologic formations when the P correction is negligible. On the other hand, the final T recovery of boreholes can be estimated from the observed transient behavior using a Horner plot, if there is no circulation of fluid within the borehole, and if the depth where the recovery is observed is not a zone of circulation loss. The borehole T measured very long time after drilling also correspond to the final T recovery, if the thermal situations mentioned above are assumed. When Th of fluid inclusions and the final T recovery are known, the thermal history of underground geologic formations in geothermal fields can be accurately delineated. (From the author's abstract by E.R.)

SASADA, M., 1988, Fluid inclusion evidence for recent temperature rising at Fenton Hill Hot Dry Rock test site west of the Valles caldera, New Mexico, U.S.A.: Int'l. Symp. on Geothermal Energy, Kumamoto and Beppu, Japan, Nov. 10-14, 1988, p. 526-529. Author at Geol. Surv. of Japan, Higashi 1-1-3, Tsukuba 305, Japan.

See Sasada, 1987b, Fluid Inclusion Research, v. 20, p. 340. (E.R.)

SASS, Eytan and BEIN, Amos, 1988, Dolomites and salinity: A comparative geochemical study: Sediment. & Geochem. of Dolostones, SEPM Spec. Pub. No. 43, p. 223-233. First author at Dept. Geol., The Hebrew Univ. Jerusalem, Jerusalem 91904, Israel.

Of pertinence to the composition of fluid inclusions in dolomite. (E.R.)

SASSANI, D.C. and SHOCK, E.L., 1988, Speciation of platinum-group elements in hydrothermal solutions (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A241. Authors at Dept. Earth & Planet. Sci., Box 1169, Washington Univ., St. Louis, MO 63130.

Mounting field, petrographic, and geochemical evidence for hydrothermal processes in the evolution of layered mafic intrusives suggests that platinum-group elements (PGE) can be transported and localized by high-P/T aqueous solutions. Experimental measurements of PGE speciation are notoriously difficult, and the available data are insufficient to address quantitatively the possible roles of hydrothermal solutions. To overcome these problems, thermodynamic data at 25°C and 1 bar can be used together with available correlation algorithms to predict equilibrium dissociation constants for aqueous PGE complexes at high P and T. These data were used in the present study to calculate the speciation of palladium in NaCl solutions at T from 0° to 750°C, P to 2 kb, and pH range from 2 to 10. Preliminary calculations at constant pH indicate that, as in the case of Pb speciation, lower-order complexes replace higher-order complexes as T increases, but these transitions occur at lower T for palladium than for Pb complexes. Along the vapor-liquid saturation curve of H_2O, $PdCl_2^{\circ}$ replaces $PdCl_4^{--}$ and $PdCl_3^{-}$ as the predominant species above ~ 250°C in low-pH, high-chloride solutions. The T of this transition is sensitive to chloride concentration, dropping to 120°C and a 0.1 m solution. These calculations also show that at 1 kb and low pH, $PdCl_2^{\circ}$, $PdCl^{+}$, $Pd(OH)^{+}$, and Pd^{++} successively predominate with increasing T. At all chloride concentrations there is a sharp transition from chloride- to hydroxide-complex dominance with increasing pH. In 0.1 and 0.5 m NaCl solutions, this shift occurs near neutral pH at all T. However, in 1.0 m NaCl solutions, $PdCl_2^{\circ}$ and $PdCl_3^{-}$ account for >95% of the Pd even into alkaline conditions. These results suggest that PGE can be readily transported as chloride complexes in the Cl-rich hydrothermal solutions inferred from petrologic studies of the Stillwater and Bushveld complexes. (Authors' abstract)

SATO, H., UEMATSU, M., WATANABE, K., SAUL, A. and WAGNER, W., 1988, New international skeleton tables for the thermodynamic properties of ordinary water substance: J. Phys. Chem. Ref. Data, v. 17, no. 4, p. 1439-1540.

SAVEL'YEVA, N.I., PROKOF'YEV, V.Yu., DOLGONOSOV, A.M., NAUMOV, V.B. and MIRONOVA, O.F., 1988, Ion chromatography applied to anions in fluid inclusions: Geokhimiya, 1988, no. 3, p. 401-408 (in Russian; translated in Geochem. Int'l., v. 25, no. 10, p. 70-77). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., USSR Acad. Sci., USSR.

Fluid-inclusion anion compositions have been determined by chromatography, which has some advantages: higher sensitivity, small sample volume (~10^{-2} ml), and scope for determining many anions. The compositions of mineralizing solution in fluid inclusions in sphalerite and calcite for the Zyryanov polymetallic deposit (Rudnyy Altai) have been determined. The solutions are mainly chloride in composition: average chlorine concentration 77 ± 33 g/kg H_2O, fluorine 3.1 ± 2.5. (Authors' abstract)

SAXENA, S.K. and FEI, Y., 1988a, The pressure-volume-temperature equation of hydrogen: Geochim. Cosmo. Acta, v.52, p.1195-1196.

SAXENA, S.K. and FEI, Y., 1988b, Fluid mixtures in the C-H-O system at high pressure and temperature: Geochim. Cosmo. Acta, v. 52, p. 505-512. See correction in v. 52, p. 2549. (E.R.)

SCAMBELLURI, M., 1988, Compositional evolution of retrograde metamorphic fluids in eclogitic rocks from the Voltri Massif, Ligurian Alps (abst.): Soc. Ital. Mineral. Petrol. "SIMP Notizie," no. 7, p. 98. Author at Dipart. di Sci. della Terra, Univ. di Genova, Italy.

In the Ligurian eclogites, fluid inclusions have been found in quartz veins crosscutting the eclogitic fabric: field and petrographic evidences indicate vein emplacement during different tectono-metamorphic events. The older veins enclose high P minerals such as sodic pyroxene, garnet and glaucophane, but have reopened during retrogressive events as testified by fluid inclusion trails crosscutting the grain boundaries of recrystallized quartz. When crosscutting the high P minerals, the healed fractures with fluid inclusions enhance retrogressive greenschist reactions.

Microthermometric measurements reveal complex fluid compositions, broadly described by the CO_2-H_2O-(Na, K)Cl system. The wide range of fluid generations may be broadly subdivided in two main groups: CO_2 and H_2O + NaCl associated inclusions and H_2O + NaCl inclusions. The main difference between the two kinds of aqueous inclusions consists in the presence of a CO_2 hydrate only detected in the H_2O + NaCl inclusions associated with the CO_2-bearing ones. The associated H_2O-CO_2 inclusions are distributed along parallel microfractures; each crack prevalently shows low density CO_2 or H_2O inclusions with the same Th of ~350°C. Probably such inclusion pairs have been generated by unmixing processes.

The H_2O + NaCl (without CO_2) inclusions are probably successive and their chronological evolution implies a decrease in salinity and Th from the oldest to the youngest generations. This is contrasting with the observed occurrence in the rock of hydration reactions, that consume water and should favor an increase in salinity of the later fluids. This contrasting behavior can be explained with the progressive dilution of the metamorphic fluid by means of meteoric waters.

The evidence of unmixing of CO_2 and H_2O inclusion pairs allows independent determination of the P-T conditions of trapping, broadly estimated at ~1 kb and 380°C. Microstructural evidence suggests that the fluid flow occurred at a lithostatic P, corresponding to a 3.5 km depth. At this shallow level the fluid was probably in disequilibrium with the rock, as testified by the high trapping T and by the thin alterations occurring at the vein walls. The lack of syn-eclogitic fluid inclusions may be due to post-eclogitic thermal peak or to the P decrease, causing the decrepitation of the early eclogitic fluids. (Author's abstract)

SCANDALE, E., STASI, F., LUCCHESI, S. and GRAZIANI, G., 1988, Growth defects and genetic medium of a quartz druse (Val Malenco, Italy) (abst.): Zeitschrift fur Kristallogr., v. 185, p. 411. First author at Dip. Geomineral., Univ. Bari, v. Salvemini, 70124 Bari, Italy.

Defect distributions and growth modalities of two quartz crystals (Val Malenco, Italy), have been investigated by X-ray diffraction topography, electron microprobe analysis and other classical mineralogical tools.

This work was undertaken to further generalize the results of previous works which evidenced the role of inclusion distributions and growth defects as important growth marks characterizing the development of crystals from the same geological environment.

In the examined crystals growth bands, precipitates, basal and pseudo basal dislocations (p.b.d.), were recognized as dominant defects. Their distribution allowed the reconstruction of the growth history of these crystals, whose initial stages of growth were almost perfect with only a few precipitates and dislocations visible. Successively a variation in the chemio-physical conditions of the microgenetic medium resulted in a change of crystal growth conditions marked by impurity absorption on prismatic faces, appearance of p.b.d. and of x {5161} growth bands, the latter characterized by an increased content of minor elements.

Optical anomalies, in particular Optic Axial Plane orientations, were observed to be related to the strain field associated to growth defects, with a general tendency to be oriented perpendicular to the most important growing faces. This behavior has resulted [been?] common to all the crystals examined, up to now, though of different geological environments.

To allow a complete generalization of the obtained results, also the growth chemio-physical conditions of these quartz crystals were defined. Careful examination of their fluid inclusions and the recognition, among others, of the included calcite, and talc individuals, allowed the characterization of the microgenetic medium: an aqueous low-salinity silica-bearing solution at about 200-400°C and no more than 3 kbar. (Authors' abstract)

SCHEDL, A., 1988, Possible geochemical implications of synthrusting growth of feldspar in the Linville Falls fault, North Carolina (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A180. Author at Dept. Geol. & Geophys., Louisiana State Univ., Baton Rouge, LA 70803-4101.

Feldspar porphyroblasts in the Linville Falls Fault Zone show a variety of unusual textures: 1) Zoned feldspar with an albite core, followed by a potassium feldspar zone which is in turn followed by an albite zone; 2) feldspar showing rotational or snowball textures with an inner core of albite and the rotational textures shown by potassium feldspar-quartz and/or potassium feldspar-muscovite intergrowths. These textures indicate that some of the feldspars grew during thrusting and that mineralogy changed from the center to the edge of the grain. Based on mineral assemblages, mineral chemistries, FI and textures, T were between 250 and 400°C and P were between 2 and 6 kb when the porphyroblasts grew. Under these conditions feldspar is brittle and stronger than the other major phases in the fault zone, quartz, muscovite and chlorite. Thus the mechanical behavior of feldspar is analogous to garnets in higher grade rocks. The mineralogically zoned porphyroblasts could form in either a closed or an open chemical system. In a closed system thermal and stress cycling due to time varying friction along the fault zone could form the observed textures. In an open system changes in the activities of Na^+, K^+, SiO_2 and H^+ of the altering fluid could cause the minerals formed by reaction to change. These changes in fluid composition could be caused by either a number of different fluid sources or chromatographic separation of a single fluid. The respective closed and open system models will be evaluated. (Author's abstract)

SCHEEPERS, R., 1986, Fluid inclusion characteristics of W-Cu-Mo mineralized, hydrothermally altered and brecciated Precambrian granites and episyenites from the southwestern Cape Province, South Africa: Int'l. South European Symp. on Explor. Geochem., IGME-AEG, 9-11 Nov. 1986, Athens, Greece, Programme with Abstracts, p. 37. Author at Univ. Stellenbosch, South Africa.

Fluid inclusion analysis of quartz and fluorite from mineralized and barren granitoids of a Precambrian granitic terrain indicates that CO_2/H_2O ratio, salinity and peak characteristics can be useful in distinguishing between these two groups of granitoids.

The mineralized Hildebrand Complex, consisting mainly of alkaligranite, quartz porphyry and episyenite is surrounded by barren older porphyritic and biotite granites. Occasional fractures in the alkaligranite and quartz porphyry contain molybdenite and chalcopyrite flakes; molybdenite is disseminated in episyenite; and veinlets and pods of massive to disseminated molybdenite, scheelite, chalcopyrite and sphalerite occur in quartz-fluorite veins cutting breccia bodies. Inclusion characteristics of gangue quartz and fluorite veins as well as quartz in alkaligranite are compared with those of quartz in barren granitoids.

CO_2:H_2O ratios of 0.75 characterize alkaligranite and associated breccia bodies as well as episyenite while surrounding granitoids have ratios of 0.12. CO_2 and H_2O homogenization spectra for alkaligranite are complex with a primary population (3.5 kb and 650°C), a main hydrothermal population (2.00-2.3 kb and 400-450°C) and two further populations with characteristic Th(CO_2) peaks at 12°C and 18°C. Quartz-spectra of mineralized breccia bodies are indicative of a main hydrothermal event corresponding to that in alkaligranite as well as populations characterized by Th(CO_2) of 12°C and 18°C. Subsidiary peaks in breccia bodies are at Th(CO_2) = 7°C and 19°C with corresponding isochore densities of 0.89 g/cm^3 and Th(H_2O) densities of 0.92 g/cm^3 and 0.94 g/cm^3. The co-existence of these two populations and their absence in barren granitoids confirm the association of metallization with brine and high-density CO_2. Brecciation and accompanying metallization took place at 0.9-1.15 kb and 190°-230°C. The presence of molybdenite in nonbrecciated alkaligranite, episyenite and quartz porphyry is ascribed to the main hydrothermal event.

High CO_2/H_2O ratios, high salinities and peak characteristics indicative of several consecutive events are considered to be better criteria for distinguishing between barren and mineralized granitoids than the mere presence of episyenites and breccia bodies. (Author's abstract)

SCHEUBEL, F.R., CLARK, D.F. and PORTER, E.W., 1988, Geology, tectonic environment, and structural controls in the San Martin de Bolanos district, Jalisco, Mexico: Econ. Geol., v. 83, p. 1703-1720. First author at Exxon Co. U.S.A., P.O. Box 1600, Midland, TX 79702.

Ore mineralization consists primarily of stromeyerite, argentite, Ag oxides, and small amounts of Au in an epithermal environment. Quartz is the primary gangue mineral and there are lesser amounts of specularite, sphalerite, fluorite, chalcopyrite, galena, pyrite, and barite. Electron microprobe analyses show that the average value of Ag in galena is only 0.08 wt % Ag and the Fe content of sphalerite is 0.95 wt % Fe. The veins are steeply dipping and the fractures pinch and swell, localizing the metals in the dilations. The late-mineralization fluids at San Martin de Bolanos were evidently of low T (140°C) and salinity (0.5 eq wt % NaCl), as interpreted from the fluid inclusion study of fluorite. Although the source of the mineralizing fluids is unknown, an adjacent rhyolitic intrusion emplaced in the western escarpment of the graben may be genetically related to mineralization. (From the authors' abstract by E.R.)

SCHIFFMAN, P., JANECKY, D.R. and BETTISON, L.A., 1988, Reaction path modeling of fluid-rock interaction in a fossil submarine hydrothermal system: Solea graben, Troodos ophiolite, Cyprus (abst.): Inst. Geophys. & Plan. Physics Ann. Report, p. 96.

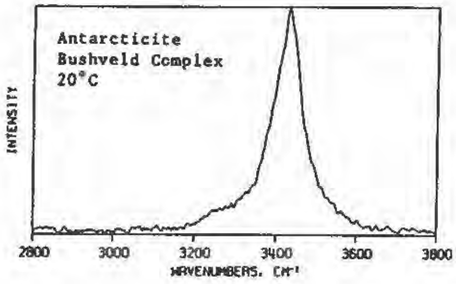
See next item. (E.R.)

SCHIFFMAN, Peter and SMITH, B.M., 1988, Petrology and oxygen isotope geochemistry of a fossil seawater hydrothermal system within the Solea Graben, Northern Troodos Ophiolite, Cyprus: J. of Geoph. Res., v.93, n.B5, p.4612-4624.

SCHIFFRIES, C.M., 1988, Fluid inclusion phase equilibria in the system $CaCl_2$-NaCl-H_2O: Cotectic relationship between antarcticite and halite (abst.): EOS, v. 69, p. 1480. Author at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008.

Chemical analyses of fluid inclusions and geothermal waters have established that $CaCl_2$ is a major constituent of hydrothermal solutions in a wide range of geological environments. Fluid inclusions containing CaCl2 are characterized by a very low eutectic T (Te < -50°C) and by the presence of antarcticite ($CaCl_2 \cdot 6H_2O$) in the subsolidus assemblage. Previous microthermometric studies of fluid inclusions in the system $CaCl_2$-NaCl-H_2O indicate that antarcticite generally melts at the ternary eutectic and either ice or hydrohalite is the next phase to melt. We report microthermometric data and Raman spectra for highly saline fluid inclusions that exhibit a completely different sequence of phase transitions. The inclusions consist of antarcticite, halite, liquid, and vapor at room T. Antarcticite is the dominant mineral in the subsolidus assemblage and it appears that ice and hydrohalite are the first phases to melt. The composition of the liquid subseqently evolves along the cotectic boundary between antarcticite and halite. The bulk composition of the fluid inclusions can be estimated from the final melting T of antarcticite (+22 to +30°C) and halite (+125 to +175°C). The inclusions we have studied are from the Bushveld Complex, and it is likely that the same sequence of phase transitions can be observed in highly saline fluid inclusions in mafic rocks from other areas. The failure to recognize antarcticite above Te would introduce large errors in the calculated fluid composition.

Hydrate daughter crystals in fluid inclusions are commonly difficult to detect and identify by optical microscopy. The presence of antarcticite is generally inferred from indirect evidence rather than diagnostic physical properties. We have confirmed the identification of antarcticite by measuring Raman spectra of individual daughter crystals in natural fluid inclusions and in synthetic fluid inclusions produced by Zhang and Frantz (1988). The room T Raman spectrum of antarcticite has diagnostic peaks at 1660 and 3430 cm^{-1} (fig. 1), corresponding to bending and stretching modes of water in the mineral structure. (Author's abstract)



SCHIFFRIES, C.M. and RYE, D.M., 1988, The Bushveld hydrothermal system: Stable isotopic data (abst.): EOS, v.69, p.527. First author at Dept. of Earth & Planetary Sci., Harvard Univ., Cambridge, MA 02138.

The Bushveld Complex is crosscut by extensive networks of hydrothermal veins (Schiffries & Skinner, next item). Although there are large variations in the modal abundance of quartz in several middle-stage veins, the $\delta^{18}O_{qtz}$ values are nearly constant (9.6±0.3 ‰). However, the δD values of fluid inclusions extracted from quartz are highly variable (-38 to -71 ‰). The $\delta^{13}C$ values of calcite (0.1 to 2.7 ‰) are similar to those of marine carbonates from the contact aureole.

The Bushveld hydrothermal system can be characterized as a rock-dominated system. The hydrothermal veins represent local regions that attained very high fluid to rock ratios as a consequence of fracture-controlled fluid flow. Most of the hydrothermal fluids were derived from external fluid reservoirs. The $\delta^{18}O$ values of the fluids were ultimately controlled by exchange with silicate minerals, particularly plagioclase, at elevated T. (Authors' abstract)

SCHLEUSENER, J.L., BARNES, H.L., DRUMMOND, S.E. and PALMER, D.A., 1988, Activation parameters and low temperature half-lives for the decarboxylation of acetate in sedimentary basin fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A150. First author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

Acetate is present in basin waters at concentrations as high as 10,000 ppm, and may be an important agent in processes as diverse as mass transport of metals and methane migration. The feasibility of models invoking acetate hinge on its half-life under the hydrothermal conditions prevalent in sedimentary basins, i.e., T up to 200°C. Previous work on acetate decarboxylation kinetics has shown that the decarboxylation reaction generally exhibits first order behavior with respect to acetate, is heterogeneously catalyzed, and is dependent on pH.

Enthalpies and entropies of activation for the decarboxylation of acetic acid in the presence of quartz, pyrite, and montmorillonite were calculated from experimental data for the reaction at 355°C and 335°C. Extrapolation of the high T data on an Arrhenius plot yields the following first order rate constants and half-lives at a typical basin T of 100°C.

Catalyst	$\Delta H*$ (kJ/mol)	$\Delta S*$ (J/mol)	$k_{100°C}$ (s^{-1})	$t_{1/2}$ $_{100°C}$(yrs)
quartz	200.3	- 72.12	9.84×10^{-20}	2.23×10^{11}
montmorillonite	222.5	- 33.75	7.41×10^{-21}	2.97×10^{12}
pyrite	65.18	-267.3	-1.82×10^{-11}	1.21×10^{3}

The low $\Delta H\ddagger$ and short half-life for the reaction in the presence of pyrite demonstrate that, in contrast to quartz and montmorillonite, pyrite is an effective catalyst. To test whether the reaction is independent of the amount of solid surface area available, acetic acid decarboxylation experiments were conducted at 355°C for a range of pyrite surface areas. It was found that the first order rate constant varied linearly with log surface area, demonstrating that the reaction is dependent on surface area. Therefore, the stability of acetate in basin fluids is a function of T, pH, and the availability of effective catalytic surfaces such as pyrite. (Authors' abstract)

SCHLICH, M., 1988, Simulation of water transport in heated rock salt: NTIS, PC A12/MF A01, EUR-10672, 273 pp. Author at Com. of European Communities, Luxembourg.

This final report contains the results of computer simulation studies on water transport in German rock salt. Based on Jockwer's experimental investigations on water content and water liberation, the object of this work was to select a water transport model that matches the water inflow which was measured in some heater experiments in the Asse salt mine. (From the author's abstract)

SCHMETZER, K., 1987, Three-phase inclusion in a yellow sapphire from Sri Lanka: Z. Dt. Gemmol. Ges., v. 36, no. 1/2, p. 79-92 (in German; English abstract).

Three-phase inclusions in untreated yellow sapphire from Sri Lanka are described. The inclusions from tabular negative crystals, which are oriented with their table parallel to the basal face of the host. The tabular negative crystals are filled with double refracting crystals as well a with one liquid and one gaseous component. (Author's abstract)

SCHMETZER, Karl, 1988, Characterization of Russian hydrothermally-grown synthetic emeralds: J. Gemm., v. 21, no. 3, p. 145-164. Author at Inst. Min. & Petrograph, Univ. Heidelberg, West Germany.

Describes and illustrates solid and fluid inclusions. (H.E.B.)

SCHMETZER, K. and BANK, H., 1988, Lechleitner synthetic rubies with natural seed and synthetic overgrowth: J. Gemm., v. 21, p. 95-101. First author at Inst. Min. & Petr., Univ. Heidelberg, West Germany.

Illustrates and discusses the fluid and solid inclusions characteristic of both the natural seed and synthetic overgrowth. (H.E.B.)

SCHMETZER, Karl and MEDENBACH, Olaf, 1988, Examination of three-phase inclusions in colorless, yellow, and blue sapphires from Sri Lanka: Gems & Gemology, v. 24, p. 107-111. First author at Mineral.-Petrogr. Inst. der Univ. Heidelberg, D-6900 Heidelberg, FRG.

Three-phase inclusions in untreated natural colorless, yellow, and blue sapphires from Sri Lanka were found to consist of liquid and gaseous CO_2 as well as needle-like to tabular crystals of diaspore. The identification of diaspore was accomplished through the use of a microscope-mounted drill system and an improved version of the Gandolfi X-ray camera. Technical details for both methods are given. The conditions under which diaspore forms as a daughter mineral in corundum are briefly discussed. (Authors' abstract)

SCHMIDT, J.M., 1988, Mineral and whole-rock compositions of seawater-dominated hydrothermal alteration at the Arctic volcanogenic massive sulfide prospect, Alaska: Econ. Geol., v. 83, p. 822-842. Author at U.S. Geol. Survey, Br. Alaskan Geol., 4200 University Drive, Anchorage, AK 99508-4667.

The strong Mg metasomatism, high Ba contents, and limited extent of altered rocks suggest a rapid influx of relatively cold seawater into a hot hydrothermal vent system. Alteration developed asymmetrically around a linear fissure, suggesting fracture control of ore fluids rather than a point source. Microprobe analyses of phyllosilicates from the Arctic area indicate two discrete mineral populations. These differences in mineral chemistry are the result of differences in protolith composition caused by hydrothermal alteration-metasomatism. (From the author's abstract by E.R.)

SCHNORR-HAYNES, P.H., 1984, Application of fluid inclusion analysis of jasperoid to exploration for micron gold deposits: MS thesis, Univ. Michigan, 90 pp.

See Schnorr et al., 1986, Fluid Inclusion Research, v. 19, p. 386. (E.R.)

SCHÖPS, Dietmar and HERZIG, P.M., 1988, Mineralogy and chemical composition of sulfides from the Leg 111 dike section of ODP Hole 504B, Costa Rica Rift: GAC, MAC, CSPG, AGC, AMC and SCGP Joint Annual Mtg., Program with Abst., v. 13, p. A109. First author at Inst. Mineral. & Lagerstättenlehre, RWTH Aachen, D-5100 Aachen, FRG.

The paragenesis and chemical composition of the sulfides and fluid inclusion data from quartz lead to an estimated T of >334°C for the formation of the mineralized veins and the alteration of the sheeted dike sequence. (From the authors' abstract by H.E.B.)

SCHOTT, J., WALTHER, J.V. and DANDURAND, J.L., 1988, Solute thermodynamic properties at high temperature and pressure modeled on solvent dielectric properties (abst.): Chem. Geol., v. 70, p. 164. Authors at Lab. Min. & Cristal., Univ. Paul Sabatier, 31062 Toulouse, France.

Fluids in the earth's crust, in addition to the solvent, H_2O, often contain high concentrations of other volatiles e.g., CO_2, CH_4, N_2) and salts (e.g., NaCl, KCl, $CaCl_2$, $MgCl_2$, $CaSO_4$). Knowledge of the thermodynamic behavior of aqueous species in these fluids is of prime importance for understanding mineral transformations in metasomatic and metamorphic processes.

Here we adopt an approach based on the dielectric constant of the solvent. The main feature on this model is to account for the nonelectrostatic contributions to excess free energy of aqueous species with aqueous species-solvent (Born) and short range (Brønsted) interactions.

This approach has been applied to analyze quartz solubility in H_2O-CO_2, H_2O-Ar, H_2O-KCl and H_2O-NaCl mixtures at high T and P. We showed that changes in the Gibbs free energy of aqueous silica can be simply deduced from changes in the dielectric constant of the fluid mixture with an uncharged monomer model for aqueous silica. Similar approach works for other neutral species ($Al(OH)_3$, H_2S) and charged species (Na^+, Ca^{++}, OH^-, ...)

As the dielectric constant for the mixture of H_2O with other volatiles or salts can be predicted to a good accuracy to high T and P, our approach allows excess free energy and speciation calculations in a wide variety of crustal solutions. (Authors' abstract)

SCHUILING, R.D., KREULEN, R. and SALEMINK, J., 1987, Metamorphic events in the Cyclades and their associated fluids, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 451-466. Authors at Dept. Geochem., Inst. Earth Sci., P.O. Box 80021, 3508 TA Utrecht, Netherlands.

Each of the alpine metamorphic phases in the Cyclades is associated with particular fluids, judging from fluid inclusion data. This paper concentrates on fluid composition and fluid behavior during the M2-metamorphism (mainly Naxos), and the M3-metamorphism (Serifos). Fluids during the M2 metamorphism on Naxos are mixed CO_2-H_2O fluids, with remarkably constant chemical and carbon isotopic composition, over the whole range of T and lithologies. They are probably derived from an external, well-mixed source below the presently exposed metamorphic series, although several isolated cases have been identified, where the fluids are locally derived. The heat added by these large quantities of externally derived fluids has probably caused the formation of the thermal dome, and there is no evidence for contemporaneous magmatic activity. The fluids in and around the granodiorite intrusion at Serifos (M3) are extremely saline brines containing NaCl-$CaCl_2$-$MgCl_2$-KCl-$FeCl_2$. Geological and isotopic evidence is in favor of a magmatic origin of these fluids, which have caused extensive skarn formation in and around the granodiorite. (Authors' abstract)

SCHWAB, R.G. and FREISLEBEN, Brigitte, 1988, Fluid CO_2 inclusions in olivine and pyroxene and their behavior under high pressure and temperature conditions: Bull. Minéral., v. 111, p. 297-306. Authors at Inst. Geol. & Min., Lehrstuhl Min., Univ. Erlangen-Nürnberg, Schlostrassegarten 5a, 852 Erlangen, Germany.

Full paper of abstract in Fluid Inclusion Research, v. 20, p. 345-346. (H.E.B.)

SCHWARTZ, Michael, 1987, The method of fluid inclusion study and its application to the Bujang Melaka Pluton, Kinta Valley: Warta Geologi (Newsletter of the Geol. Soc. of Malaysia), v. 13, no. 6, p. 255-264. Author at Federal. Inst. Geosci. & Natural Resources, FRG.

The range of salinities (0-38 wt % NaCl eq.) and Th (100°-420°C) as well as the presence of mixed CO_2-H_2O inclusions in the Bujang Melaka Pluton are usual features of Sn-W-bearing greisen and veins.

The minimum P of entrapment as determined from the CO_2 phase density, salinity and total Th of the CO_2-H_2O-(NaCl) inclusions ranges from 0.25 to 1.9 kb. This is in agreement with the presence of zeolite (stilbite) in the contact aureole, which is stable up to a depth of 0.9 and 2.5 km under lithostatic and hydrostatic conditions, respectively. The high P limit of 1.9 kb implies a depth of 7 km under lithostatic load. The system may have evolved from lithostatic to hydrostatic during the intrusion.

The Th of the mixed CO_2-H_2O inclusions are true minimum Tt (250°-420°C) whereas the T for the aqueous inclusions (100°-360°C) have to be corrected for P[sic]. For 1 kb, the P correction is 80°-110°C for Th range of 100°-360°C and salinities of 1-25% (Potter, 1977). Thus the Tt corrected for an average P of 1 kb are 190°-460°C; they are quite close to the bulk Th of mixed CO_2-H_2O inclusions (250°-420°C). (E.R.)

SCHWARZ, D., 1986, Genetic classification of emerald occurrences: Anais XXXIV Congresso Bras. Geol., Goiania, Goiás, v. 4, p. 1854-1862 (in Portuguese; English abstract).

The author presents a classification of five genetic types based among other features on their inclusion contents. The fluid inclusions are mentioned only according to their number of phases present. (K. Fuzikawa)

SCHWARZ, D., EIDT, Th. and COUTO, P.A., 1988, The emeralds of Socoto, Bahia, Brazil: Occurrence and characteristics: Z. Dt. Gemmol. Ges., v. 37, no. 3/4, p. 89-112 (in German; English abstract).

The emerald occurrence of Socoto is characterized by granite batholiths, whose pegmatites (source of Be) intruded the rocks of the Serra de Jacobina and, in the contact zone with Fe- and Cr-rich rocks (ultrabasites) formed the emerald. Many different solid inclusion minerals were found.

Some of the most striking inclusion features of the emeralds from Socoto are phenomena whose formation is directly related to the emerald growth process: growth tubes and channels, regions with an elevated concentration of inclusions, color zoning/growth striae. Further inclusions are different types of fractures and fissures, fluid inclusions, two-phase inclusions and rarely three or multiphase inclusions. (From the authors' abstract by E.R.)

SCHWARZ, D., HÄNNI, H.A., MARTINS, F.L., Jr. and FISCHER, M., 1988, The emeralds from Fazenda Boa Esperança (Tauá, Ceará), Brazil: Occurrence and characteristics: Z. Dt. Gemmol. Ges., v. 36, no. 3/4, p. 133-147 (in German; English summary). First author at Ouro Preto, Brazil.

The emerald producing Fazenda Boa Esperança (Tauá/Ceará), Brazil, is presented, the regional and local geology and the properties of the emeralds are discussed.

The emerald occurrence is situated in biotite schists and tremolite-bearing schists with phlogopite and chlorite. Its formation is closely related to anatectic pegmatites which have intruded into the rock series. The emeralds are associated with very large apatite crystals and, locally, corundum.

Chemical analyses show low contents of Cr_2O_3 and V_2O_3 of <0.25 wt.% and rather high contents of FeO (0.91-1.17 wt.%), MgO (2.42-2.69 wt.%) and Na_2O (1.69-1.96 wt.%).

The substitutions

$$Al^{3+,VI} = (Mg,Fe)^{2+} + Na^{+,Channel}$$
$$Al^{3+,VI} = (Fe,Cr,V)^{3+,VI}$$

explain the low Al-contents.

The Tauá emeralds have many mineral inclusions. So far phlogopite, tremolite, molybdenite, allanite and apatite have been identified. In addition, accumulations of very small fluid drops and/or mineral dust and plane cavities, mostly showing a one-phase filling, occur. The concentrations of these inclusions diminish the gem quality of the emeralds. (Authors' abstract)

SCHWEITZER, Janet, 1988, Interaction of physical and chemical processes during chlorite breccia development, Sacramento Mountains, SE California (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A212. Author at Dept. Geol. Sci., VPI & SU, Blacksburg, VA 24061.

The evolution of chlorite breccia, frequently associated with low-angle extensional faults in metamorphic core complexes, involves complex interaction of mechanical and chemical processes. Chlorite breccia is found in brittle shear zones (BSZ) in mylonitic hornblende-biotite granodiorite of the Sacramento Mountains, SE California. BSZ's, separated by intervals of relatively intact rock, are typified by a variably thick (5 cm to 10 m) zone of completely altered (chl + ep + cc + qt ± hem) host rock bounded on top and bottom by chlorite breccias. Fracturing cataclasis and alteration, characteristic of chlorite breccias, decreases in intensity away from the zone of extreme chloritization.

In chlorite breccia, granodiorite clasts are separated by zones of microbreccia. A systematic microstructural examination shows that development of microbreccia involves transgranular cracking followed by displacement, and possibly rotation of clasts, accompanied by grain-size reduction, host-rock alteration and precipitation of new minerals. Healed fractures, decorated by fluid inclusions which form conjugate or parallel sets, are found in granodiorite both with and without microbreccia and suggest that fluids were present during cracking. Fractures, which often parallel fluid inclusion trails, are commonly decorated by very-fine grained ep ± chl. As displacement of clasts occurred, microbreccia developed in zones of irregular thickness along microfaults. Grain-size reduction resulted from a combination of physically breaking the rock into smaller pieces and chemical alteration of host grains. Mineralogic changes observed include the reaction of fsp to mu ± chl ± ep ± cc; hbl to bt ± chl or ep ± cc; and bt to chl. Networks of microcracks extend off microfaults into host rock grains, further breaking and altering grains and widening microbreccia zones.

With increasing strain, overall grain size continued to decrease, microbreccia zones coalesced, and alteration became more intense. The correlation between intensity of mechanical disruption of granodiorite and chemical alteration indicate that the two are interdependent during microbreccia development, and hence, during chlorite breccia evolution. (Author's abstract)

SCOTT, G.L., 1987, The origin of chlorine in the fluids of the Tongonan geothermal system, Philippines: Proc. 9th NZ Geothermal Workshop 1987, p. 93-95. Author at Dept. Geol. & Geothermal Inst., Univ. Auckland.

Two extreme arguments have been used in the past to explain the origin of chlorine in high T geothermal fluids, namely, chlorine is continuously leached from the surrounding country rock, or it is of magmatic origin. Two further variations are that chlorine can originate from both sources with one or the other predominating. Assuming a constant Cl concentration of 10,000 mg/kg and minimum natural upflow rate of 1.6×10^{-2} km^3/year for the Tongonan system fluids (the present system is at least 5×10^5 years [old] and the rocks still contain up to 500 mg/kg Cl), chlorine could have been totally leached from 10 km^3 volume of reservoir rocks in the center of the field during the initial 10^3 years of geothermal activity at Tongonan. The most likely option for the origin of chlorine in the present-day Tongonan fluids is that HCl gas has reacted at magmatic T with the granite heat-source rocks to form a halite-saturated water phase and a saline vapor. The vapor condenses (NaCl dissociates) in the overlying meteoric water system at sub-critical T and sets up convective circulation typical of water-dominated geothermal systems. A minor Cl contribution could still come from the reservoir rock. (Author's abstract)

SEAL, R.R., II, CLARK, A.H. and MORRISSY, C.J., 1988, Lake George, southwestern New Brunswick: A Silurian, multi-stage, polymetallic (Sb-W-Mo-Au-base metal) hydrothermal center, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 252-264. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI, USA.

The Lake George polymetallic center, located in southwestern New Brunswick, comprises and early scheelite (-molybdenite) stockwork system and a later complex of stibnite-bearing veins, hosted by folded, pelitic and marly, Upper Silurian metasediments and a monzogranite cupola. Fluid inclusion and mineralogical data for the three main stages of mineralization indicate that mineralization formed from a minimum of three distinct thermal pulses. Initial T for all three pulses ranged from +550°C to 480°C, and each pulse subsequently cooled to as low as 142°C. Chemically, all three fluids were grossly similar; they consisted of moderately saline brines (av. salinities, 6.7 to 10.0 eq. wt. % NaCl) and contained moderate amounts of CO_2 (nil to 17 mole %). The close spatial and temporal association of the veinlets and veins with igneous activity and their initially elevated T strongly suggest that all stages of mineralizing fluid were at least in part related to magmatic activity. (From the authors' abstract by H.E.B.)

SEN, S.K. and BHATTACHARYA, A., 1988, Granulites of Satnuru and Madras: A study in different styles of fluid-melt interaction (abst.): Terra cognita, v. 8, p. 253. Authors at Indian Inst. Tech., Kharagpur, India.

The Satnuru granulites, situated just south of the celebrated Kabbal locality in Karnataka, share several features with their counterparts in the Madras (Pallavaram) area. The petrographic spread is very similar, though the relative abundances of rock types are not the same. A notable difference is the presence of granites and granite gneisses at Satnuru. Pegmatite, aplites or leptynites, and migmatites are profusely developed in both the areas. Several geothermometers and geobarometers combine to indicate 700 ± 30°C and 5.7 ± 0.7 kb as the equilibration PT at Satnuru; for the Madras rocks they yield 780 ± 30°C and 7.1 ± 1.0 kb. The aH_2O values were estimated from the equilibria phlogopite + 3 qtz = 1.5 enst + ksp + H_2O (charnockites) and phlogopite + sill + 2 qtz = pyrope + ksp + H_2O (metapelites).

The relationship observed between TiO_2 and aH_2O in the Madras rocks was caused by internal buffering combined with dehydration melting. This relation is absent in the Satnuru suite where the activities have not been internally buffered but externally controlled. It is envisioned that partial melting in this area was synchronous with CO_2 influx. Strong evidence in support of equilibration under fluid influx is the narrow and characteristic compositional ranges observed in garnet, bitotite and orthopyroxene in different assemblages. Fluid inclusion data point to entrapment of CO_2 during peak metamorphic conditions.

The subtle compositional and equilibrium signatures indicate vapor-absent dehydration melting with fluid activities internally buffered at Madras, and dehydration melting synchronous with CO_2 influx at Satnuru. (From the authors' abstract by H.E.B.)

SEREZHNIKOV. A.I., 1988, Behavior of silica in natural solutions under acid conditions: Dokl. Akad. Nauk SSSR, v. 298, no. 1, p. 210-214 (in Russian). Author at All-Union Sci.-Research Inst. of Hydrogeol. & Engrg. Geol., Zelyonyi near Moscow, USSR.

On the basis of the silica content (10-500 mg/ml) in natural waters from Kamchatka (pH 2.0-8.0), the SiO_2 behavior is discussed and the silicate dissolution mechanisms are shown. (A.K.)

SEWARD, T.M., 1988, Solute association in hydrothermal fluid systems (abst.): Chem. Geol., v. 70, p. 164. Author at Inst. Mineral. & Petrogr., ETH-Zentrum, CH-8092 Zürich, Switzerland.

An understanding of mass transport and fluid-mineral equilibria in hydrothermal systems is premised on our knowledge of the chemistry of metal complex and ion pair equilibria at elevated T and P. Association equilibria are enhanced in high T aqueous solutions because of changes in ion-solvent interaction associated with expanding water structure.

Ion pairing of so-called 'strong' electrolytes has been studied at T >350°C and P to 5 kbar, however, there are few studies of ion association in the intermediate T from 25 to 300°C. Recent experimental studies demonstrate the continuum of change from barely detectable ion association at ambient T to appreciable ion pairing at T >250°C. For example, the cumulative equilibrium formation constant for $CaCl_2^0$ extends from log K_2 = +0.24 at 150°C to +4.70 at 360°C.

The existence of weak ion pairs in strong electrolyte solutions at low T (i.e., at 25°C) has been regarded with scepticism by some workers because their presence may only be indirectly inferred. However, first row transition metal chloride complexes are also weak but may be studied spectrophotometrically. New data on $NiCl^+$ and $FeCl^+$ formation indicate stabilities similar to the $HCl°$ ion pair. For example log K_1 for the formation of $NiCl^+$ and $HCl°$ at 25°C are -0.85 and -0.67 respectively. At 300°C log K_1 ($NiCl^+$) = +1.72 and log K_1 ($HCL°$) = +1.51.

The importance of such data in geochemical modelling of hydrothermal mass transport and deposition will be discussed. (Author's abstract)

SEYFRIED, W.E., Jr., BERNDT, M.E. and SEEWALD, J.S., 1988, Hydrothermal alteration processes at mid-ocean ridges: Constraints from diabase alteration experiments, hot-spring fluids and composition of the oceanic crust: Canadian Mineral., v. 26, p. 787-804. Authors at Dept. Geol. & Geophys., Univ. Minnesota, Minneapolis, MN 55455, USA.

Results of diabase alteration experiments at elevated T and P have been combined with theoretical calculations to define the metasomatic processes reflected by the chemistry of hot-spring fluids and the chemistry and mineralogy of metabasalts dredged from mid-ocean ridges and observed in ophiolite outcrops on land. These data demonstrate that Mg-, Ca- and Na-fixation reactions are affected differently by different alteration conditions, and thus it is likely that each dominates a specific region within the submarine geothermal system. Mg fixation characterizes the downwelling limbs of subseafloor convection cells, whereas Ca and Na fixation are related more fundamentally to hydrothermal upflow zones, Ca at depth and Na nearer the surface. Ca removal from solution and attendant H^+ production are enhanced greatly by decompression effects, which contribute as well to oxidation and stabilization of epidote relative to other calcic alteration phases. Epidote-rich rocks (epidosites) observed at the base of sheeted intrusive complexes of numerous ophiolites likely represent the effects of Ca fixation, decompression, and oxidation within deep-seated, permeable upflow zones. The local, integrated, fluid/rock mass ratio of epidosite reaction zones may be as high as 1000. Experimental models of ridge-crest hydrothermal processes suggest that epidote and plagioclase solid solutions control the chemistry and pH of hot-spring fluids. T and P of ~385-400°C and 300-400 bars characterize the reaction zone of fluids discharging from black-smoker vents at 21°N, East Pacific Rise. Reaction-zone conditions (T, P) can be estimated for virtually all hot-spring fluids provided that salinity effects and retrograde processes caused by conductive cooling and/or subseafloor mixing are unambiguously accounted for. (Authors' abstract)

SHAIDETSKAYA, V.S., 1988, Geochemical peculiarities of solutions in inclusions in halite from the Devonian rock salt of the Dneprovsk-Donets Basin, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 127-131 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 367-368. (E.R.)

SHARMA, V.K. and MILLERO, F.J., 1988, The oxidation of Cu(I) in electrolyte solutions: J. Solution Chem., v. 17, no. 6, p. 581-599.

SHAW, D.M., HIGGINS, M.D., TRUSCOTT, M.G. and MIDDLETON, T.A., 1988, Boron contamination in polished thin sections of meteorites: Implications for other trace-element studies by alpha-trace image or ion microprobe: Am. Mineral., v. 73, p. 894-900. First author at Dept. Geol., McMaster Univ., Hamilton, Ontario L8S 4M1, Canada.

Of possible pertinence to search for B, etc., in inclusions. (E.R.)

SHCHEGOLEVA, G.N., KOGARKO, L.N., ROMANCHEV, B.P. and KRIGMAN, L.D., 1988, The parameters of ultra-agpaitic alkaline pegmatite-formation, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 73-79 (in Russian).

SHCHEKA, S.A., MALAKHOV, V.V., ROMANENKO, I.M. and MALAKHOVA, V.G., 1988, The fluid regime of basite-ultramafic magmas (based on a study of inclusions in minerals, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 29-34 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 368-369. (E.R.)

SHCHERBA, G.N., ed., 1988, Rare-metal mineralization in Kazakhstan: Alma-Ata, Nauka Pub. House, 223 pp. (in Russian). ISBN 5 - 628-00054-X; 1000 copies printed; price 4 roubles.

The main structures bearing rare metal ores are described from the viewpoint of the new concept of geotectogenes. The inner structure, ore productive magmatism [and] distribution of ore deposits are characterized. The sequence of position of rare metal zones, belts, knots, and systematics of rare metal formations, including new types and subtypes, are demonstrated. Geologic and genetic stereomodels of the main types of deposits of W, Mo, Sn, Bi and other elements are proposed, and some questions concerning prognosis in prospecting are considered. The book is useful for geologists studying the problems of metallogeny and ore deposits. (Editor's abstract)

Table of Contents

(Translation by T.M. Sushchevskaya)

SHCHERBA, G.N., SENCHILO, N.P., KUDRYASHOV, A.V., GUBAIDULIN, F.G. and KORMUSHIN, V.A., 1988, Models of typical rare metal deposits of Kazakhstan, in Obolenskii, A.A., et al., eds., Genetic models of endogenetic ore formation, Izdat. "Nauka," Novosibirsk, p. 248-256.

The three-dimensional compositional zoning and inclusion temperature isotherms for deposit types (Ta-Nb-Zr-TR), (Ta-Nb-Sn), (W-Mo-Sn-Bi), and (Mo) are presented, plus three analyses of inclusion fluids for H_2O, CO_2, H_2S, H_2, CH_4, CO, K, Ca, Na, Mg, Cl, HCO_3, F, and SO_4. (E.R.)

SHEETS, R.W., BODNAR, R.J., CRAIG, J.R. and AUSBURN, K.E., 1988, Precious metal mineralization at the Morning Star deposit, San Bernadino County, California (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A142. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Disseminated precious metal mineralization at the Morning Star Gold Deposit, San Bernadino County, CA, occurs in the hanging wall of the north-south trending Morning Star Fault. Mineralization is hosted by the weakly peraluminous Late Jurassic-Early Cretaceous Ivanpah granite, which is the earliest of six intrusive phases of the Teutonia Batholith. Pervasive propylitic alteration occurs in both the hanging wall and foot wall. Weak argillic ± sericitic alteration occurs only in the mineralized hanging wall. Base and precious metal mineralization is associated with quartz ± calcite, occurring both as cements in stockwork breccia zones and as veins subparallel to the fault.

Two stages of mineralization have been identified based on petrographic and electron microprobe analyses. An early stage of quartz, calcite, pyrite, hematite, chalcopyrite, galena, sphalerite, Ag-bearing tetrahedrite, and electrum is followed by a later stage of pyrite, covellite, digenite, hematite, acanthite, uytenbogaardtite(?) (Ag_3AuS_2), native bismuth, and electrum. Electrum occurs as free grains and fracture fillings or as inclusions in pyrite during the early stage of mineralization, and as rims around early electrum or as intergrowths with covellite and acanthite in the later stage. Electron probe analyses indicate that early-formed electrum has an average fineness of 650, whereas all late-stage electrum has fineness greater than 800.

FI in quartz associated with the early stage of mineralization contain H_2O and liquid and vapor CO_2 at room T and have salinities of 6 wt.% NaCl eq. Microthermometric measurements ($Tm(CO_2) = -56.6 \pm 0.1°C$) indicate that the gas phase is essentially pure CO_2 and, based on room T phase ratios, the inclusions contain 10-20 mole % CO_2.

Structural, mineralogical and FI observations suggest that early Morning Star mineralization was structurally controlled and spatially and temporally associated with fluids of metamorphic affinity. Ore grades have subsequently been increased as a result of late stage hydrothermal processes. (Authors' abstract)

SHELEH, Fantina, 1988, Ultramafic xenoliths in the basalt of southern Syria: Petrography, geochemistry and fluid inclusions (abst.): 12th Reunion des Sci. de la Terre, 27-29 April, 1988, Abstracts, p. 121 (in French). Author at Univ. Damascus, Damascus, Syria.

Ultramafic xenoliths from basalt at the following locations in southern

Syria were studied: Djabel Al-Maneh, Tel Al-Khaldieh, Tel Thannoun, Tel Sahwat Al-Khudre, Telimtan and Tel Al-Ajeilate. The xenoliths are peridotite and pyroxenite (mainly spinel lherzolite, harzburgite, wehrlite and websterite) and associated hydrated types bearing olivine, ortho- and clinopyroxene, spinel and hornblende. Fluid inclusions in the xenoliths contain CO_2 and vary in shape: elongate, tubular, round, negative crystal, flat. They may be distributed uniformly in their host, or near the extremities, or in healed fractures, or isolated. Two generations are distinguished: 1. early, dating from the formation of the rock; and 2. later, due to the contamination of volcanic gases during transport to the surface. Using T from the model of Wood and Banno (1973) and densities of early inclusions, P-T conditions of 13 ± 0.2 kb and 1200 ± 25°C were determined. These conditions are remote from the stability field of diamond. (Author's abstract, translated and abbreviated by C.J. Eastoe)

SHELTON, K.L. and SO, C.-S., 1988, Gold-rich mesothermal vein deposits, Republic of Korea: Products of highly evolved meteoric waters (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A301. First author at Dept. Geol., Univ. Missouri, Columbia, MO 65211.

Au-rich mesothermal vein deposits of the Jungwon area, R.O.K., are composed of massive quartz veins <1.0 m wide occupying fault planes in Precambrian gneiss. K-Ar dating of alteration sericite indicates a Late Jurassic age for mineralization, similar to that of a nearby granodiorite. Veins are Au-rich and sulfide-poor with ore shoots <200 m in horizontal and vertical extent. Ore grades average 10.2 g/ton Au with an average Au/Ag production ratio of 6:1.

Fluid inclusions indicate Au was deposited at 375° to 290°C from relatively dilute fluids ($\approx$ 4 wt. % eq. NaCl) containing $\approx$ 15-25 mole % CO_2. Evidence of fluid unmixing indicates P of $\approx$ 1,300 bars. Au deposition was a result of decrease of sulfur activity caused by sulfide deposition and/or H_2S-loss accompanying CO_2-effervescence.

Isotopic compositions of ore fluids ($\delta^{18}O$ = 5.0 to 7.7; δD = -78 to -113 per mil) indicate that Au was deposited from a highly evolved meteoric water that underwent extreme ^{18}O- and moderate D-enrichment. Mineralogy and ore fluid chemistry are similar to those of mesothermal Au vein deposits of the Canadian Cordillera, Archean greenstone belts and the Mother Lode district. The diversity of host rocks in these deposits may indicate that host rock petrology is not a controlling factor in the formation of mesothermal Au vein deposits. These observations, together with our geochemical studies of Korean deposits, validates a more general application of meteoric water models for the formation of mesothermal Au vein deposits. (Authors' abstract)

SHELTON, K.L., SO, C.-S. and CHANG, J.-S., 1988, Gold-rich mesothermal vein deposits of the Republic of Korea: Geochemical studies of the Jungwon gold area: Econ. Geol., v. 83, p. 1221-1237. First author at Dept. Geol., Univ. Missouri, Columbia, MO 65211.

Au vein deposits of the Jungwon area are among the first documented examples of mesothermal Au deposition in the Republic of Korea. The deposits are composed of massive quartz veins up to 1.0 m wide which occupy fault planes in Precambrian gneiss. K-Ar dating of alteration sericite (146-156 m.y.) indicates a Late Jurassic age for ore mineralization, similar to that of a nearby granodiorite. The veins are Au rich and sulfide poor with ore shoots up to 200 m in horizontal and vertical extent. Ore grades average 10.2 g/ton Au with an average Au/Ag production ratio of 6:1.

Fluid inclusion data indicate that Au was deposited between 375° and 290°C from relatively dilute fluids ($\approx$ 4 eq. wt % NaCl) containing $\approx$ 15 to

25 mole % CO_2. Evidence of fluid unmixing (CO_2 effervescence) indicates P of 1200 to 1500 bars. Au deposition was likely a result of decrease of S activity caused by sulfide deposition and/or H_2S loss accompanying fluid unmixing.

Measured and calculated compositions of ore fluids in the Jungwon area ($\delta^{18}O$ = 5.0 to 7.7‰; δD = -78 to -113‰) indicate that Au was deposited from a highly evolved meteoric water that underwent extreme ^{18}O enrichment and moderate D enrichment. Mineralogy and ore fluid chemistry of the Jungwon area deposits are similar to those of mesothermal Au vein deposits of the Canadian Cordillera, Canadian Archean greenstone belts, and the Mother Lode district of California. The diversity of host rocks in these deposits indicates that host-rock petrology is not a controlling factor in the formation of mesothermal Au vein deposits. These observations, together with our geochemical studies of Korean deposits, may validate a more general application of meteoric water models for the formation of mesothermal Au vein deposits. (Authors' abstract)

SHENBERGER, D.S., GAMMONS, C.H. and BARNES, H.L., 1988, The solubility of gold and silver in aqueous sulfide solutions (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 74. Authors at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802, USA.

Experimental solubility data have been obtained for elemental Au and Ag sulfide in aqueous H_2S-NaHS solutions at T from 150-350°C for Au and from 25-300°C for Ag sulfide. Au solubility was measured at pH's ranging from 2 to 8 with the oxidation state of the system buffered by either sulfate-sulfide equilibria or hydrogen gas. Ag sulfide solubility measured at near neutral pH's is supplemented by low pH data for Ag sulfide from the literature and unpublished data from our laboratory. The above data were used to calculate equilibrium constants for:

(1) $Me(s) + H_2S(aq) = MeHS^\circ + 0.5H_2(g)$

(2) $Me(s) + H_2S(aq) + HS^- = Me(HS)_2^- + 0.5H_2(g)$

where Me represents either Au or Ag. Reaction (1) has only a slight T dependence for both Au and Ag, whereas reaction (2) has a strong positive T dependence for Au but a weaker T dependence for Ag. Equilibrium constants for the above reactions are in good agreement with published values. In addition, solubilities calculated by Brown (1986) from well precipitates at Broadlands, New Zealand, are in close agreement.

Au and Ag solubility was calculated as a function of T, oxidation state, pH, and chloride activity to evaluate the transport potential of hydrothermal fluids. This demonstrates that although the experimental solubilities for reaction (1) are much less than for (2), reaction (1) controls the solubility in acidic natural systems. Au-Ag solubility ratios vary widely as a function of solution T, pH, and oxidation state. Depending on the mechanism involved, precipitation may yield Au-Ag ratios vastly different from their ratios in solution. (Authors' abstract)

SHEPHERD, T.J. and MILLER, M.F., 1988, Fluid inclusion volatiles as a guide to tungsten deposits, southwest England: Application to other Sn-W provinces in western Europe, in Mineral deposits within the European community, J. Boissonnas and P. Omenetto, eds.: Publ. Springer-Verlag, Berlin, p. 29-52.

Analysis of fluid inclusion volatiles in vein quartz, by gas mass spectrometry, demonstrates a clear distinction between Sn- and W-bearing ore fluids in the Hercynian metallogenic Sn-W province of SW England. The W fluids are characterized by enhanced levels of CO_2 and N_2 (>0.5 mol%), a distinctive CO_2-N_2-Ar signature and strong CO_2-N_2 covariance. By contrast, the Sn fluids are depleted in dissolved gas; thus confirming the widely recognized 'W-CO_2' association. These features are sufficiently well developed to warrant their use as an exploration index for granite-related vein/greisen-type W deposits in the region. Comparison with W deposits in NW England, Eire, France and Portugal reveals similarly high levels of dissolved gas and an inter-correlation between CO_2, CH_4 and N_2 which are independent of the age of mineralization. This suggests that such features are fundamental characteristics of W fluids and allows the exploration criteria established for SW England to be applied to other Sn-W provinces in western Europe. However, no specific signature or volatile content is universally applicable, and in keeping with good exploration practice it is recommended that routine orientation studies be carried out in each district. (Authors' abstract).

See also Shepherd et al., Fluid Inclusion Research, v. 19, p. 398-399. (E.R.)

SHERWOOD, B., FRITZ, P., FRAPE, S.K., MACKO, S.A., WEISE, S.M., WELHAN, J.A., BLOMQVIST, R. and LAHERMO, P.W., 1988, Hydrocarbon and helium geochemistry in the crystalline environment - The Canadian and Baltic Shields (abst.): Chem. Geol., v. 70, p. 40. Authors at Dept. Earth Sci., Univ. Waterloo, Waterloo, Ontario, N2L 3G1, Canada.

In both the Canadian and the Baltic Shield of Finland, large discharges of CH_4 and associated hydrocarbon gases have been documented in numerous exploration boreholes. Locally, such gas occurrences are He and H_2-rich (up to 20% and 30% by volume respectively). Chemical and isotopic analyses tentatively indicate an abiotic origin for the Canadian Shield CH_4's. Similarities in compositional and isotopic signatures of CH_4, H_2, and He in both environments suggest that abiogenic gas formation may be a characteristic feature of Precambrian Shield terrains.

The occurrence of abiogenic CH_4, and high concentrations of H_2 and He have been suggested as potential evidence for mantle degassing. However, preliminary $^3He/^4He$ results from both Canada and Finland are indicative of crustal He. Thus, if it can be assumed that the He and CH_4 originate from the same source, a mantle origin for CH_4 in these environments seems unlikely.

The occurrence of high levels of H_2 gas in boreholes in both Canada and Finland indicate that H_2 may be involved in kinetically-controlled, inorganic processes of CH_4 formation. Reactions involving isotopically light H_2 typical of that generated in the Canadian Shield and in other ultramafic/mafic environments could explain the deuterium-depleted nature of the crystalline CH_4's. Detailed isotopic studies of the associated H_2 and CH_4 are underway, but as yet no specific generating mechanism has been identified. (Authors' abstract)

SHIBUE, Y., 1988a, Fluid inclusion data on some Japanese molybdenum deposits (abst.): Mining Geol., v. 38, no. 1, p. 63 (in Japanese;.translation courtesy S. Takenouchi).

Fluid inclusions in quartz of the Seikyu Mo-quartz veins are mostly liquid inclusions but those containing liquid CO_2 or CO_2 gas hydrate occur rarely. Th ranges from 325° to 191°C, and salinity from 18 to 4 wt.% NaCl eq. High salinity and high T (<380°C) fluid inclusions are reported from the Hirase, Busshoji, Higashiyama, Kawahira, Ohnobe, Seikyuu, Nakatatsu-Sennou and Shisou Mo deposits. On the other hand, such high-salinity and high-T fluid inclusions are only reported from the Itage deposit for W deposits. Such a difference in the mode of occurrence of fluid inclusions reflects an important difference of physicochemical conditions between the Mo and W mineralization. (Author's abstract)

SHIBUE, Yasuhiro, 1988b Importance of tungstate species for the transport of tungsten in hydrothermal solution: Case studies on major Japanese tungsten deposits: J. Min. Petr. Econ. Geol., v. 83, p. 51-68. Author at Geosci. Inst., Hyogo Univ. of Teacher Education, Shimokume 942-1, Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

Thermodynamic calculations on the stability relations among various tungsten species are performed in order to elucidate the possible form of tungsten during the transportation in hydrothermal solution, using the knowledge of the fluoride and chloride concentrations. Based on the fluorine contents in micas and topaz and the fluid inclusion data, it is calculated that HF/H_2O and HCl/H_2O fugacity ratios in the natural hydrothermal solutions responsible for major Japanese tungsten deposits at the Kaneuchi, Ohtani, Takatori, Fujigatani, Kiwada, and Kuga range from $10^{-3.15}$ to $10^{-5.91}$ and are less than $10^{-3.33}$, respectively. P and T conditions for the formation of the studied deposits are summarized and calculated to be from 1 to 2 kbars, and from 300° to 600°C, respectively. Oxygen fugacities are assumed to be those defined by the $C\text{-}CO\text{-}CO_2$ buffer as the most reducing condition encountered. Based on the P, T, $f(O_2)$, $f(HF)/f(H_2O)$, and $f(HCl)/f(H_2O)$ conditions evaluated for the studied deposits, thermodynamic calculations are performed to compare the stabilities of halogen-bearing species with those of tungstates. Calculated results show that H_2WO_4 may be a predominant species in the natural hydrothermal solutions responsible for the formation of major Japanese tungsten deposits. (Author's abstract)

SHIBUE, Yasuhiro, 1988c High cadmium contents of sphalerites from major tungsten deposits in Japan: Mineral. J., v. 14, no. 4, p. 115-125.

Indexed under "Fluid Inclusions." (E.R.)

SHIGA, Yoshihide and URASHIMA, Yukitoshi, 1988, Au-Ag-Te ores from epithermal quartz veins of the Kushikino mine, Kagoshima Prefecture, Japan: Mining Geol., v. 38, no. 5, p. 375-384. Authors at Dept. Geol., Col. Liberal Arts, Kagoshima Univ., Kagoshima, 890 Japan.

The Kushikino mine is located at the northeastern part of Kushikino City in Kagoshima Prefecture, Japan. The ore deposit is of representative epithermal Au-Ag quartz vein type developed in Miocene andesite. Two Te-concentrated veins were investigated in the present study: The Arakawa No. 5 and Shinpi No. 1 veins. The veins are largely composed of quartz, calcite, chlorite/smectite interstratified mineral, apatite, and ore minerals. The following ore minerals were confirmed to occur, as determined with ore microscope and electron microprobe: sphalerite, chalcopyrite, galena-clausthalite solid solution, pyrite, hessite, altaite, calaverite, petzite, electrum, sylvanite, etc., in the order of decreasing abundance.

A tentative low-T phase diagram for the Au-Ag-Te system was constructed in the present study on the basis mainly of the observed mineral assemblages and the chemical compositions of the coexisting minerals. The equilibrium T for the assemblages, inferred from the experimental studies carried out by previous investigators, is ~100°C (at least <120°C). On the other hand, the Th measured on fluid inclusions in quartz and calcite associated with ore minerals, range from 200° to 250°C. If it is the case that the ore minerals precipitated from fluids in this T range, there is a significant T difference, as large as more than 100°C, between the precipitation T and the equilibrium T. This may be attributed to the rapid reaction rate during retrograde process and the relatively slow cooling rate in natural environments. (Authors' abstract)

SHIKAZONO, Naotatsu, 1988, Oxygen and carbon isotope ratios of calcite and evolution of hydrothermal activities in the Seigoshi gold-silver mining district, Japan: Mining Geol. Spec. Issue, 1988, no. 12, p. 1-16. Author at Geol. Inst., Fac. Sci., Univ. Tokyo, Bunkyo-ku, Hongo, Tokyo 113, Japan.

O and C isotope measurements were carried out for calcite occurring in propylitically altered rocks and Au-Ag-quartz veins in the Seigoshi Au-Ag mining district Japan. The total range of $\delta^{18}O$ for 38 calcites is wide, being from 1.7 to 23.7‰, while the $\delta^{13}C$ range is relatively narrow, being from -7.4 to 1.2‰. $\delta^{18}O$ values of calcite occurring as veinlets exhibit a larger variation than those occurring as disseminations in altered volcanic rocks.

These isotopic data, together with Th data of fluid inclusions [in calcite and quartz], and the mineralogical data of alteration minerals coexisting with calcite are interpreted in terms of the T, water/rock ratio and boiling of fluids during the history of the hydrothermal system. Calcites in the propylitically altered rocks have formed from a meteoric water which interacted with volcanic rocks under the water/rock ratios (in atomic % O) of 0.1 to 10 during early stage of hydrothermal activity at T = 300-150°C. The calculated water/rock ratios for fluids responsible for vein calcite and quartz of the later hydrothermal stages are estimated to be 0.5 to 50. Boiling of fluids may have caused a part of the variations in $\delta^{18}O$ and $\delta^{13}C$ of later stage hydrothermal fluids. Hydrothermal solution responsible for the Au-Ag mineralization is calculated to have had $\delta^{18}O$ values between -2 and -7‰, which are similar to or several per mil higher than that of the present-day local meteoric water. This suggests that the ore fluid was meteoric water in origin which interacted with volcanic rocks at high water/rock ratios (1 to more than 10). (Author's abstract)

SHIKAZONO, Naotatsu and SHIMIZU, Masaaki, 1988, Electrum: Chemical composition, mode of occurrence, and depositional environment: The Univ. of Tokyo Museum Bull. no.32, 81 p.

Includes a plot (p.50) of the Th of 36 deposits containing electrum vs. their silver content, and a similar plot vs. salinity. (E.R.)

SHIKINA, N.D., ZOTOV, A.V. and KARTASHOVA, L.F., 1988, The behavior of Sb in the Sb-H_2O-H_2 system at elevated temperatures: Geokhimiya, 1988, no. 1, p. 123-127 (in Russian; translated in Geochem. Int'l., v. 25, no. 8, p. 105-109).

SHIMIZU, N., GURNEY, J.J. and MOORE, R.O., 1988, Trace element abundance patterns of garnet inclusions in diamonds (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 74. First author at EAPS, MIT, Cambridge, MA 02139, USA.

Abundances of Sc, T, V, Cr, Y, Zr and REE were measured in individual garnet inclusions in diamonds for Finsch and Koffiefontein kimberlites with a Cameca IMS 3f ion microprobe using the energy filtering technique coupled with empirical relationships between secondary ion intensities and concentrations. The ranges in concentrations (107-205 ppm Sc; 41-987 ppm Ti; 307-470 ppm V; 2.2-23.5 ppm Zr; 2.5-7.6x chondrite Ce; 7-30x chondrite Sm; 1.1-5x chondrite Yb) and concentration ratios (Ti/Zr 11-30; Ti/Sc 0.33-4.8) observed in the peridotite-type garnets are consistent with those previously reported (Shimizu & Richardson, 1986). Chondrite normalized patterns are sub-parallel among samples and show general LREE enrichment with a hump at Nd-Sm. A positive correlation seems to exist between Ca and overall REE abundance levels. Eclogite-type garnets, in contrast, are generally more enriched in Ti (500-3750 ppm), Y and Zr (39-91 ppm) and have higher Ti/Zr (up to 40) and Ti/Sc (14-53) ratios than the peridotite-type. They have LREE depleted patterns. It is speculated that the peridotite and eclogite types are derived from significantly different materials and possibly through different processes as well.

Variability of trace element abundances at a single locality (at Finsch Ti varies by a factor of 8, REE by a factor of 3) coupled with other traits such as LREE enrichment and unusually low Ti/Zr seems to argue against a simple igneous origin for the peridotite-type garnets and thus their host diamonds. (Authors' abstract)

No volatiles or fluids reported. (E.R.)

SHMULOVICH, K.I., KALINICHEV, A.G. and BELONOZKO, A.B., 1988, The study of natural fluid model at high pressures and temperatures (abst.): Terra cognita, v. 8, p. 77.

SHOCK, E.L., 1988a Organic acid metastability in sedimentary basins: Geology, v. 16, p. 886-890. Author at Dept. Earth & Planet. Sci., Washington Univ., St. Louis, MO 63130.

Thermodynamic calculations indicate that CO_2 in sedimentary basins may be in stable redox equilibrium with organic acids found in basinal brines, but that CH_4 is not. These calculations also show that the high concentrations of carboxylic acids are far from equilibrium with decarboxylation reactions. A compilation of recent analyses of carboxylic acids from aqueous solutions associated with petroleum reservoirs shows that there is no trend in acid concentration with T; however, inspection of these data at ~100°C indicates that acetic and propanoic acids are in homogeneous metastable equilibrium. Oxygen fugacities indicated by this metastable assemblage are consistently lower than those set by iron-oxide assemblages; this is not surprising, because both hematite and magnetite are unstable relative to siderite in the presence of detectable concentrations of acetic acid. (Author's abstract)

SHOCK, E.L., b1988, Prediction of the hydrothermal solubility of hydrocarbons (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A95. Author at Dept. Earth & Planet. Sci., Washington Univ., St. Louis, MO 63130.

Ample evidence from submarine hydrothermal systems and deep wells in sedimentary basins indicates that hydrocarbon migration proceeds at T in excess of 200°C in the presence of aqueous solutions. At these conditions, migration is controlled largely by the solubility of hydrocarbons in the aqueous phase. Although experimental data at T >75°C is limited to ~20 liquid and solid alkanes and aromatics, these data show that solubility of all hydrocarbon species increases above ~40°C at vapor-liquid saturation P for H_2O. Recently developed corresponding states methods and correlation algorithms allow prediction of the aqueous solubility of hundreds of petroleum hydrocarbons at hydrothermal conditions from equations of state for both pure hydrocarbons and aqueous species. The general applicability and accuracy of these methods is supported by thermodynamic calculations of hydrocarbon solubility which closely represent all high-T/P data (up to 405°C and 2 kb). Preliminary calculations indicate that at the conditions of primary migration of petroleum hydrocarbons from shales containing hydrogen-rich kerogen (T >200°C), the solubilities, by weight, of many hydrocarbons are greater than that of quartz. Similar calculations at the T and P at which fluids exit the hydrothermal vents in the Guaymas Basin indicate that the activity of aqueous octane (a representative alkane) in equilibrium with octane liquid is ~0.45, while that of aqueous naphthalene (a representative aromatic) in equilibrium with pure naphthalene is ~2.5. Taking account of the activities of individual hydrocarbons in petroleum, and activity coefficients for organic species in aqueous electrolyte solutions, suggests that many available hydrocarbons can be transported readily in hydrothermal solutions. (Author's abstract)

SHOCK, E.L. and HELGESON, H.C., 1988, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Correlation algorithms for ionic species and equation of state predictions to 5 kb and 1000°C: Geochimica Cosmo. Acta, v. 52, p. 2009-2036.

See corrections published in same journal, v. 53, p. 215, 1989. (E.R.)

SHOJI, T. and ENJOJI, M., 1988, Glass inclusions: An indicator of geothermal heat source: Proc. 10th New Zealand Geothermal Workshop, p. 275-279. First author at Min. Dev. Engrg., Univ. of Tokyo, Japan.

Many geothermal fields are located in the terrains where volcanic rocks are dominant. These rocks are considered to be products prior to the present geothermal activity on a series of magmatism. In the Kirishima geothermal field, southwestern Japan, many glass inclusions are found in phenocrysts of plagioclase, pyroxene and olivine of the volcanic rocks. At present, most of them consist of a bubble and a clean or devitrified glass with or without daughter and/or trapped minerals. Each inclusion should have consisted of a silicate melt and trapped minerals when it was isolated, and a bubble and dxls were formed during the cooling and solidification process of the melt. The Th at which a bubble disappears, therefore, gives information concerning the T of trapped magma. The glass inclusions have Th ranging from 800°C to 1400°C. The values may suggest that the present T of geothermal heat source in the Kirishima geothermal field is 800°C at the highest. (Authors' abstract)

SHOJI, Tetsuya and KOBAYASHI, Shoichi, 1988, Fluid inclusions found in jadeite and stronalsite, and a comment on the jadeite-analcime boundary: J. Min. Petr. Econ. Geol. (Japan), v. 83, p. 1-8 (in English). First author at Dept. Min. Dev. Engrg., Faculty Engrg., the Univ. Tokyo, Hongo 7-3-1, Tokyo 113, Japan.

Many fluid inclusions are found in jadeite and stronalsite newly reported from southwestern Japan. Th is 365°C to 110°C. The existence of fluid inclusions suggests that the jadeite rock was affected by later hydrothermal activity. These hydrothermal fluids played an important role for the formation of analcime and grossular, which are main constituents of the veinlets cutting the jadeite rock. Any isochore passing through the Th does not intersect the experimentally determined jadeite-analcime boundaries in the T-P diagram. This means that the equilibrium boundary between both the minerals passes through the lower P region than the experimental results. (Authors' abstract)

SHUBAT, M.A. and McINTOSH, W.S., 1988, Geology and mineral potential of the Antelope Range mining district, Iron County, Utah: Utah Dept. Natural Resources Bull. 125, 26 pp. First author at Utah Geol. & Min. Survey, Salt Lake City, UT 84108-1280.

The district contains many occurrences of epithermal, base and precious metals mineralized veins. Quartz from the Bullion Canyon area contains inclusions indicating boiling at T of 200-205°C. Many higher Th values are assumed to be from heterogeneous trapping. (E.R.)

SHUGUROVA, N.A. and TSIMBALIST, V.G., 1988, Determination of the cation composition (gold, silver, copper, lead, and zinc) from the liquid phase of inclusions by atomic-absorption, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 75-80 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 379. (E.R.)

SHUKLA, Vijai and BAKER, P.A., eds., 1988, Sedimentology and geochemistry of dolostones: SEPM Spec. Pub. 43.

SIDDAIAH, N.S. and RAJAMANI, V., 1988, Geochemistry and origin of gold mineralization in the Kolar schist belt (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 142-143. Authors at Sch. Environ. Sci., Jawaharlal Nehru Univ., New Delhi-110067, India.

A review, quoting published fluid inclusion data. (E.R.)

SIGURDSSON, Haraldur and CAREY, Steven, 1988, The far reach of Tambora: Natural History, v.97, n.6, p.67-73.

Includes some discussion of the quantities of S, Cl, and F emitted, based on analysis of glass inclusions (ER).

SIMKIV, Zh.A., 1988, A study of the chemical composition of inclusion solutions by the method of aqueous extraction from minerals, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 59-64 (in Russian).

SIMMONS, S.F. and BROWNE, P.R.L., 1988, Mineralogic, alteration and fluid studies of the Mt. Muro gold prospect, central Kalimantan, Indonesia (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 472-474. Authors at Epithermal Mineralization Res. Unit, Geol. Dept., Auckland Univ., Private Bag, Auckland, New Zealand.

Fluid inclusion studies indicate that mineralizing solutions were dilute, <2.5 eq. wt. % NaCl, and ranged between 210° to 240°C. Coexisting liquid-rich and vapor-rich fluid inclusions, quartz pseudomorphs of angel wing calcite, and ubiquitous vein adularia further suggest that these fluids were at, or close to, boiling conditions and indicate that a favorable environment for Au deposition existed. Vein mineralization formed at a minimum paleo-depth of ~200 to 400 meters within the geothermal environment. (From the authors' abstract)

SIMMONS, S.F., GEMMELL, J.B. and SAWKINS, F.J., 1988, The Santo Nino silver-lead-zinc vein, Fresnillo district, Zacatecas, Mexico: Part II. Physical and chemical nature of ore-forming solutions: Econ. Geol., v. 83, p. 1619-1641. First author at Geol. Dept., Univ. Auckland, Private Bag, Auckland, NZ.

The Santo Nino vein is a classic example of Ag-base metal epithermal mineralization and is one of the principal ore bodies in the Fresnillo district. The extensive vein structure once represented a major conduit for fluids in the shallow upflow region of a magma-generated hydrothermal system. Continuous fracturing and vein opening permitted recurring passage of fluids which resulted in four stages of mineralization; the first three contain quartz, sulfides, and sulfosalts, whereas the final stage is dominated by calcite.

Fluid inclusion studies on the quartz, calcite, and sphalerite indicate that mineralizing solutions ranged between 170° to 260°C and 9 to 60 bars P and were close to or at boiling conditions throughout the mineralizing period. The best estimate of the paleosurface elevation is ~100 m above the present-day surface. However, considerable vertical fluctuation of the piezometric surface of boiling solutions apparently occurred during regional hydrothermal activity; for the period in which the Santo Nino vein was mineralized, the piezometric boiling surface was situated well below the paleosurface, possibly by as much as 150 to 200 m.

Three distinct fluids were identified on the basis of freezing data and

O and H isotope compositions. Quartz-saturated solutions were dilute, averaging 2 eq wt % NaCl and less than 4 wt % CO_2. These solutions evolved from extensive exchange reactions between country rock and deep circulating meteoric waters ($\delta^{18}O_{water}$ = 3.9 to 7.7‰, δD = -43 to -74‰), but may additionally include some magmatic waters. Stage IV calcite-saturated solutions were also dilute, probably CO_2-bearing, and were derived from an isotopically distinct source region, possibly one undergoing contact metamorphism $\delta^{18}O_{water}$ = 14.8 to 17.0‰, δD = -48 to -60‰). Sphalerite-saturated solutions, in contrast, were brines (8.5 to 12.0 eq wt % NaCl max, δD = -30 to -61‰), which were introduced repeatedly in the early parts of the first three stages of mineralization and were present in the vein structure only briefly. These intermittent brines were the mineralizing fluids responsible for Ag and base metal deposition.

He isotope compositions ($^3He/^4He$) measured for inclusion fluids from quartz, calcite, and sulfides (stages I, II, III, and IV) range from 1.1 to 2.1 times the atmospheric ratio (R_a). These values suggest the presence of a dilute component of mantle He, derived from a subjacent magmatic region at the time of hydrothermal activity. However, He isotope signatures appear to be completely separated from the other hydrologic factors which governed the chemistry and stable isotope compositions of the distinct hydrothermal fluids.

A model for ore genesis is proposed in which metalliferous brine solutions, of magmatic origin, were injected repeatedly and episodically into a hydrothermal system dominated by dilute, quartz-saturated solutions. Metal sulfides and sulfosalts precipitated rapidly under the influence of boiling conditions. Stage IV calcite precipitation marks the end of ore deposition and the influx of fluids from a distinctly different source region. (Authors' abstract)

SIMONSON, J.M., ROY, R.N., MRAD, D., LORD, P., ROY, L.N. and JOHNSON, D.A., 1988, The thermodynamics of aqueous borate solutions. II. Mixtures of boric acid with calcium or magnesium borate and chloride: J. Solution Chem., v. 17, no. 5, p. 435-446.

SIROTIN, S.K., 1988, Thermobarogeochemical features of the heterogenization [?] and degasification of solutions during near-surface volcanogenic ore formation, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 85-93 (in Russian)

SISSON, V.B., CLOSMANN, C.E., LEEMAN, W.P., TRUSCOTT, M.G. and HOLDAWAY, M.J., 1988, Boron loss during low pressure progressive metamorphism of central Maine and southern Chugach Mountains, Alaska (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A342. First author at Dept. Geol., Rice Univ., Houston, TX 77251.

A feature common to two sequences of low P amphibolite facies metamorphic rocks, one in central Maine and the other in the eastern Chugach Mountains of southern Alaska, is the disappearance of toumaline with increased metamorphic grade. The loss of tourmaline corresponds to a decrease in the whole rock B content. At greenschist facies, the B content of samples from Alaska depends on the host lithology: metapelites average 39 ppm B, metasiltstones average 20 ppm B and basaltic metatuffs only have 3-5 ppm B. The B content of associated synmetamorphic quartz veins is low and related to salinity of fluid inclusions; as salinity increases so does the B content of the quartz vein.

Metamorphism in both pelitic sequences is generally isochemical relative to a constant aluminum reference frame for major elements. In both suites of samples, most trace elements are immobile during progressive metamorphism. For example, the whole-rock Zn content does not vary with metamorphic grade or with presence or absence of staurolite. The B concentration decreases with increased T. In addition to B loss, both suites become depleted in volatiles with increasing grade. B is probably released during tourmaline breakdown, incorporated into a fluid and/or melt phase and removed from the rock. Geothermometry and mineral assemblage data suggests that tourmaline breaks down around 620-650°C. The B remaining in the rocks after tourmaline breakdown is hosted in sillimanite, micas, and the fine grained ground mass as observed in α-track maps. B content of associated anatectic melts in southern Alaska is low. The occurrence of late stage quartz-tourmaline veins and tourmaline-bearing pegmatites suggest that B is dissolved in pneumatolytic fluids. These preliminary measurements imply that if the rock is not buffered with respect to B, it will be partitioned into the fluid phase and may not influence anatectic processes in pelitic assemblages. (Authors' abstract)

SISSON, V.B. and LEEMAN, W.P., 1988, The role of boron and fluids in high temperature, shallow level metamorphism of the Chugach Metamorphic Complex, Alaska (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 139-141 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 165-167). Authors at Dept. Geol., Rice Univ., Houston, TX 77251-1892.

The possible role of boron (B) involvement in granite equilibria and generation of melts during crustal metamorphism has been a focus of speculation in recent literature. The majority of the fluid preserved as fluid inclusions in the Chugach Metamorphic Complex is CO_2-rich and the P fluids have isochores which pass through peak metamorphic conditions. The B content of the host quartz veins is low [< 1 ppm]. One vein in the amphibolite facies region does preserve a transition from H_2O-CO_2 mixture to pure CO_2. The salinity of the H_2O component is not great enough to suggest fluid immiscibility as a cause for the composition change at these metamorphic conditions (550°C and 3 kbar). However, a possible explanation for the composition change is that the water has been incorporated into either the intrusive tonalites or locally derived melts. Thus, the CO_2 may represent a residual fluid.

These preliminary measurements imply that the B content of rocks in the Chugach Metamorphic Complex is not sufficient to influence the processes of partial melting at low P. (From the authors' abstract by E.R.)

SKEWES, M.A. and CAMUS, F., 1988a Fluid inclusions and the mechanism of gold deposition in the Chilean epithermal deposit El Bronce de Petorca (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A352. First author at Dept. Geol. Sci., Univ. Colorado, Boulder, CO 80309.

Fluid inclusions in veins of the polymetallic epithermal deposit El Bronce de Petorca, hosted in Cretaceous volcanic rocks associated with the Morro Hediondo caldera in the Andes of central Chile, indicate that the zone of precious metal (Au) mineralization formed approximately 400 to 1200 m below the paleosurface. Au mineralization is observed to underlie the zone of boiling of hydrothermal fluids indicating that other mechanisms were responsible for Au precipitation.

The fluid inclusions associated precious metal mineralization at El Bronce have Th that range between 230 to 345°C and salinities that range from 5 to 10 wt. % NaCl eq. T and salinity tend to decrease from the deeper to the shallower levels of the deposit. Calculated vertical variations of the enthalpy of the hydrothermal fluids suggest that a mechanism of mixing of fluids was operating during the formation of the deposit. In areas where both enthalpy and salinity decrease, precipitation of Au occurred, indicating that mixing was an important factor in Au mineralization. Hot saline ore-rich ascendent fluids mixed with cooler meteoric waters producing first precipitation of Fe, Cu, and Zn sulfides and subsequent Au. Where the gradients of decreasing salinity are the most extreme Au grades are highest. (Authors' abstract)

SKEWES, M.A. and CAMUS, Francisco, 1988b, Fluid inclusions and the deposition mechanism of noble metals in the epithermal ore deposits of El Bronce de Petorca, Chile: Rev. Geol. Chile, v. 15, no. 1, p. 31-39 (in Spanish).
See previous item. (E.R.)

SKIRIUS, C. and ANDERSON, A.T. Jr., 1988, Pre-eruptive H_2O and CO_2 across the plinian to ash-flow transition of the Bishop Tuff (abst.): EOS, v.69, p.529. First author at Dept. of Geophys. Sci., Univ. of Chicago, Chicago, IL 60637.

Pumice lumps from selected vertical positions in a 10m thick exposure through the plinian deposit into overlying ash-flow yielded quartz phenocrysts with inclusions of rhyolitic glass. The inclusions were analysed by Fourier transform infrared (FT-IR) spectroscopy for their H_2O and CO_2 contents. Measurements at Chicago using a microbeam arrangement and a MCT detector result in absorbances (at 5200/cm (molec. H_2O), 4500/cm (OH), and 2350/cm (CO_2)) which are within 20 % of those obtained on the same samples by Newman and Stolper at Caltech using a different instrumental setup. Analyses of 8 plinian inclusions from 3 levels (lowest 60 % of exposed plinian) yielded about 6 wt. % H_2O and 0.005 wt % CO_2. Analyses of 5 inclusions from two levels in the lowermost part of the ash-flow yielded similar H_2O and up to 0.015 % CO_2. Inclusions from lumps of pumice from the same stratigraphic levels have comparable ranges in H_2O and CO_2. Evident variations in H_2O and CO_2 occur between inclusions within the same phenocryst: the H_2O may be constant and CO_2 vary by 5X or the H_2O may range over 1-2% with CO_2 constant. The intracrystal H_2O variations show that the inclusions preserve a memory of variable H_2O in the evolving magma. The ranges of initial H_2O and CO_2 overlap across the transition from plinian to ash-flow deposit. (Authors' abstract)

See also Anderson, et al., this volume (E.R.).

SMALLEY, P.C., BLOMQVIST, R. and RÅHEIM, A., 1988, Sr isotopic evidence for discrete saline components in stratified ground waters from crystalline bedrock, Outokumpu, Finland: Geology, v. 16, p. 354-357.

SMITH, B. K., 1988, HRTEM analysis of defects in experimentally-deformed San Carlos olivine - Effect of chemical environment on dislocation core structures (abst.): EOS, v.69, p.477.

SMITH, P.M., AYER, J.A., BUCK, S., MORRICE, M.G., SANBORN-BARRIE, M., BLACKBURN, C.E., BROWN, P.E. and DAVIS, D.W., 1988, Style, controls and timing of gold mineralization in the Lake of the Woods Greenstone Belt, northwestern Ontario, Canada: Evidence for a plutonic connection (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 45-47. First author at Ontario Geol. Survey, Toronto, Ontario.

Petrographic, microprobe, geochemical and fluid inclusion studies of both regional metamorphic and alteration patterns, and Au-related alteration indicate that Au was deposited at P of 3 ± 1 kilobars, and from 250 to 400°C. The mineralizing fluid was low in salinity, alkaline to slightly acidic, and generally enriched in H_2O, CO_2, K, SiO_2, and S. These characteristics are consistent with devolatilization related to contact metamorphism and/or a magmatic source. (From the authors' abstract)

SNEE, L.W., SUTTER, J.F., and KELLY, W.C., 1988, Thermochronology of economic mineral deposits: Dating the stages of mineralization at Panasqueira, Portugal, by high-precision $^{40}Ar/^{39}Ar$ age spectrum techniques on muscovite: Econ. Geo., v.83, p.335-354. First author at Dept. of Geo., Oregon State Univ., Corvallis, OR 97331.

Published fluid inclusion data have been used to estimate a muscovite argon closure at ≈325°C during rapid cooling or short reheating and at ≈270°C during slow cooling or extended reheating. Argon-loss patterns displayed by all dated muscovites resulted from reheating after original closure; the mechanism for this argon loss appears to have been argon transport by volume diffusion. Thus, $^{40}/Ar^{39}Ar$ age spectrum dating of muscovite can be used to evaluate thermal conditions controlling argon diffusion as well as age, duration, and number of episodes of mineralization. (From the authors' abstract)

SNOW, J., and BROWN, G., 1988, Sri Lankan ekanite: A gemmology study club report: The Australian Gemmologist, v.16, no.9, p.346-348.

Illustrates fluid and solid inclusions in ekanite from this locality. (H.E.B.)

SO, C.-S., CHI, S.-J. and CHOI, S.-H., 1988, Geochemical studies on Au-Ag hydrothermal vein deposits, Republic of Korea: Jinan-Jeongeup mineralized area: J. Min. Petr. Econ. Geol., v. 83, p. 449-471. Authors at Dept. Geol, Korea Univ., Seoul 136-701, Republic of Korea.

Electrum-sulfide mineralization of the Jinan-Jeongeup Au-Ag area was deposited in three stages of structurally controlled quartz and calcite veins that fill N-S and NW-SE-tending shear zones. Radiometric dating indicates that mineralization is Late Cretaceous age (75-80 Ma). Fluid inclusion and sulfur isotope data show that ore mineralization was deposited between 330° and 250°C from fluids with salinities of 1 to 8 wt.% eq. NaCl and a $\delta^{34}S_{\Sigma S}$ value of 3 to 6‰. Evidence of fluid boiling indicates a range of P from ≈500 m in a hydrothermal system which alternated from lithostatic toward hydrostatic conditions. Au was carried as a thiosulfide complex in slightly acidic, chemically reducing fluids. Au-Ag deposition was likely a result of cooling coupled with boiling.

Measured and calculated H and O isotope values of ore-forming fluids indicate a significant meteoric water component in the Jinan-Jeongeup ore fluids. Comparison reveals that all Korean Au-Ag deposits display various degrees of ^{18}O-enrichment relative to meteoric water, produced by exchange with hot igneous rocks. However, individual mines and districts have relatively narrow ranges of H and O isotope compositions which are directly related to their Au/Ag ratios and which reflect their depths of formation. Ag-rich epithermal deposits display the smallest ^{18}O shifts, indicating a lesser degree of water-rock interaction at shallow depths of formation (<750 m). Korean-type Au-Ag deposits display intermediate ^{18}O shifts, indicating a moderate degree of water-rock interaction at intermediate depths of formation (750 to 1,500 m). Au-rich mesothermal deposits display the largest ^{18}O shifts, indicating the highest degree of water-rock interaction at relatively great depths of formation (>4.5 km). This suggests a relationship between depth and degree of water-rock interaction in Korean deposits. All of these Au-Ag-bearing deposits have fluids which are dominantly evolved meteoric waters, but only deeper systems with higher degrees of igneous rock interaction are exclusively Au-rich. (Authors' abstract)

SOBOLEV, A.V. and NAUMOV, V.B., 1985, First direct proof of the presence of water in ultramafic melts and their estimated water content: Dokl. Akad. Nauk SSSR, v. 280, no. 2, p. 458-461 (in Russian; translated in

USSR Acad. Sci., Earth Sci. Sec., 1985, v. 280, no. 1, p. 102-105, 1986, p. 102-105). Authors at Vernadskiy Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

Abstract in Fluid Inclusion Research, v. 19, p. 411-412. (E.R.)

SOBOLEV, N.V., ed., 1988, Thermobarogeochemical studies of processes of mineral formation: Novosibirsk, Nauka Pub. House, 217 pp. (in Russian). Publications of the Inst. of Geol. & Geophys., no. 733. ISBN 5-02-028807-1; 650 copies printed; price 3 roubles.

This volume, dedicated to Yu.A. Dolgov on his 70th birthday, consists of 23 individually-authored papers on a variety of subjects. It will be abstracted in the next volume. (E.R.)

SOLOMON, G.C. and ROSSMAN, G.R., 1988, NH_4^+ in pegmatitic feldspars from the southern Black Hills, South Dakota: Am. Mineral., v. 73, p. 818-821. First author at Converse Environ. Consultants California, Pasadena, CA 91105, USA.

Trace amounts of ammonium ion (0.7 mol% NH_4^+ substitution) have been identified from the infrared spectra of alkali feldspars from pegmatites occurring in the southern Black Hills district, South Dakota. The spectroscopic data indicate that the ammonium is structurally bound, most likely in the M site of the microcline. These results indicate that ammonium was likely a component of metamorphic fluids present during anatexis of metasedimentary rocks in the southern Black Hills district. (Authors' abstract)

SOMAN, K. and KOTOV,E.I., 1988, CO_2-rich fluid inclusions in chrysoberyl-pegmatites from south Kerala, India: P-T estimates and genetic implications: Geol. Soc. India Memoir 11, p. 79-89. First author at Centre for Earth Sci. Studies, Akkulum, Thuruvikkal P.O., Tvm.-31, India.

Early Palaeozoic chrysoberyl pegmatites are ubiquitous within the granulite facies khondalite terrain of south Kerala, India. Mineralogy of the pegmatites and the khondalites show striking similarities. Chrysoberyl-quartz and sillimanite-andalusite associations, and prevalent graphic textures are characteristic of the pegmatites. Fluid inclusion studies indicate the presence of high density CO_2-rich inclusions in pegmatite minerals. These and garnet-biotite mineral thermometry allow a P-T estimate of 500-760°C and 2.4-5.2 kb for the formation of pegmatites and 520-590°C and 2.8-4.0 kb for the formation of chrysoberyl in the pegmatites. Gas analyses indicate the additional presence of H_2, and rarely N_2 and CH_4 in the inclusions. Leachate analyses suggest that the pegmatitic fluids were rich in Ca, Na and Cl and that these were slightly acidic in nature. (Authors' abstract)

SONG, Xinhua, ZHAN, Xunruo and WU, Guozhong, 1988, Study of Dengfuxian granite by melting experiment: Scientia Geol. Sinica, no. 3, p. 247-258 (in Chinese; English abstract). Authors at Beijing Graduate School, Wuhan College of Geology.

It is confirmed by calculations from melting experiments of water-saturated Dengfuxian granite and analysis of petrological phase diagrams, in the light of experimental petrology, that Dengfuxian granite was formed by magmatic crystallization instead of granitization. At the same time, it is shown that the initial melting T was related not only to the rock composition, but also to the conditions during the formation process. Besides, in fluoride-bearing water-saturated experiment, the addition of fluoride can lower the initial melting T and change the stability of various minerals in the magmatic system as well, thus making mica and quartz more stable, acidic plagioclase unstable, and not affecting the stability of potassium feldspar. (Authors' abstract)

SONYUSHKIN, V.E. and PETROVA, T.L., 1988, The use of a range of electron-microscope methods for studying the morphology and material 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 (ISBN 5-12-000435-0), p. 10-20 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 394. (E.R.)

SOOM, M., ARMBRUSTER, Th. and STALDER, H.A., 1988, OH-rich topaz from Alpine fissures in Triassic dolomites near Lugnez, Graubünden (Mesozoic cover of Gotthard Massif, Swiss Alps): Schweiz. Mineral. Petrogr. Mitt., v. 68, p. 141-155. First author at Naturhistorisches Museum, Bernastr. 15, CH-3005 Bern, Switzerland.

An Alpine fissure topaz, occurring together with quartz and dickite in Triassic dolomites near Lugnez, Graubünden (Switzerland) is described. Optical data and cell dimensions were determined for one selected single crystal which was previously heated at 950°C yielding: $\alpha = 1.624$, $\gamma = 1.637$, $2V_Z = 53°$, $a = 4.6548(8)Å$, $b = 8.820(2)Å$, $c = 8.380(2)Å$, $a \parallel X$, $b \parallel Y$, $c \parallel Z$. Without heating topaz shows characteristic sector zoning. OH-F substitution was estimated from cell dimensions and optical data leading to molar F/(F + OH)-values between 0.75 and 0.85. Fluid inclusion measurements in syngenetic quartz indicate that topaz grew in NaCl-bearing, high CO_2 hydrothermal solutions at T above 250°C and P around 2.5-3.0 kbar. Towards the end of mineralization CO_2-water unmixing occurred, liberating a CO_2-rich vapor phase which favored the precipitation of carbonates and sulfides. (Authors' abstract)

SOUISSI, Fouad, 1987, Case study and conditions of formation of the fluorite deposits (Pb, Zn, Ba) from the Jebel Zaghouan (J. Stah and Sidi Taya), and from the Jebel Oust (northeastern Tunisia) (abst.): PhD dissertation, Univ. Paul Sabatier, 39 Allees Jules Guesde, 31400 Toulouse, France (in French; translated by R.P. Moritz).

The study of the fluorite deposits (Pb, Zn, Ba) of Jebel Stah, Sidi Taya, and Jebel Oust integrated a geological, mineralogical, and geochemical investigation of the host rocks, and a characterization of the fluids responsible for the genesis of these deposits. The deposits of J. Stah and J. Oust are located in lower Lias carbonates, whereas Sidi Taya is hosted by upper Jurassic limestones. The carbonate rocks have been either dolomitized (J. Stah), or silicified (J. Stah, Sidi Taya). The mineralizations are located at lithological discontinuities. They are mainly composed of fluorite. Galena, sphalerite, tennantite-tetrahedrite, cinnabar, and Ba- and Sr-bearing sulfates (Sidi Taya) are present locally.

Microthermometric studies of the fluid inclusions indicate that fluorite in J. Oust was formed between 200 and 250°C from fluid with a high salinity (31 to 34% eq. NaCl); fluorite in Sidi Taya and in J. Stah was deposited between 120 and 160°C from fluids with salinity in the range of 18 to 21% eq. NaCl; and a third generation of fluorite in J. Stah indicates an increase of T (between 175 and 180°C), and a decrease in salinity (10% eq. NaCl). Ionic species in the inclusions are mainly Na, K, Ca, Mg, Cl, and SO_4. T of the fluids in the source reservoir are estimated to be 300°C. Combined with P estimates of these deposits, they indicate that the Triassic rocks are a likely source of the ore components. (From the author's abstract)

SPASENNYKH, M.Y. and BANNIKOVA, L.A., 1988, The interpretation of oxygen and hydrogen isotopes variations in hydrothermal systems by quantitative dynamics model, in Isotopic geochemistry of ore-forming processes, Yu. Shukolyukov, ed.: "Nauka," Moscow, p. 21-39 (in Russian). (Continued)

The problems of construction and application of the mathematical models describing O and H isotope exchange between water and rocks along flow lines in hydrothermal systems are discussed. The theoretical consideration is based on the examination of numerical solutions of the sets of equations describing one-dimensional filtration and isotope exchange proceeding in surface reaction or diffusion reaction mechanisms. The dimensionless numbers are derived. In the monomineral approximation the effects of thermodynamic, kinetic and dynamic parameters on time-space distribution of isotope compositions along flow lines are investigated in detail. The authors discuss some questions of the behavior of isotopes in polymineral systems and systems characterized by unstable mineral compositions. The problems are solved under different time-space-T distribution conditions. The comparison of the behavior of O and H isotopes in systems under such conditions is studied. On the basis of these considerations the authors formulate the requirements of the models describing isotopes variations in real situations.

The problems of the correct interpretation of isotope data by the models at issue are discussed. The approach to interpretation is based on the comparisons of curves reflecting theoretical and real space isotope distributions in wall rocks and time dependences of fluid and mineral on different stages of mineralization. The methods for estimation of water sources, directions of filtration, the values of water/rock ratios characterizing each stage of mineralization and the values of integral water/rock ratios are considered. (English abstract by T.M. Sushchevskaya)

SPECZIK, S., 1988a Relation of Permian base metal occurrences to the Variscan paleogeothermal field of the Fore-Sudetic Monocline (southwestern Poland): Spec. Publ. Soc. Geol. Appl. Mineral Deposits 5, p. 12-24.

Indexed under "Fluid Inclusions." (E.R.)

SPECZIK, S., 1988b Relation of Permian base metal occurrences to the Variscan paleogeothermal field of the Fore-Sudetic Monocline (southwestern Poland), in G.H. Friedrich, P.M. Herzig, eds., Base Metal Sulfide Deposits: Springer-Verlag, Berlin.

Fluid inclusion studies and vitrinite reflectance measurements establish T of alteration processes that affected Carboniferous, older Paleozoic, and Precambrian basement rocks of the Fore-Sudetic Monocline of southwest Poland. Surprisingly high T determined for these processes (ranging from 180 to 350°C), and the locally extensive alteration indicate the importance of geothermal influence. The high-T geothermal field of the Fore-Sudetic Monocline shows various heat anomalies related to paleohighs and strongly tectonically disturbed basement. These anomalies are spatially related to the areas of known Zechstein base metal occurrences of the Kupferschiefer type. It is suggested that one controlling factor leading to the formation of the Kupferschiefer mineralization was the availability of thermal energy. Mobilization and gradual preconcentration of base metals during the Late Variscan was due to anomalous heat flow related to Variscan plate motions. This Variscan heat flow is considered to be mainly convective. (Author's abstract)

SPIRAKIS, C.S. and HEYL, A.V., 1988, Possible effects of thermal degradation of organic matter on carbonate paragenesis and fluorite precipitation in Mississippi Valley-type deposits: Geology, v. 16, p. 1117-1120. Authors at U.S. Geol. Survey, Box 25046, Fed. Center, Denver, CO 80225.

Heating of organic matter to progressively higher T causes a sequence of chemical changes in which carbonate minerals are first dissolved, then precipitated, and then again dissolved. The initial carbonate dissolution is related to the production of organic acids. As heating continues, organic acids begin to decompose to carbon dioxide and methane. This addition of carbon dioxide to a solution with an organic-acid pH buffer causes carbonates to precipitate. Eventually, a T is reached at which any remaining organic acids quickly decompose. Addition of carbon dioxide to a solution in which carbonate species rather than organic acids now control the pH lowers the pH and causes renewed carbonate dissolution. The similarity of this sequence to the carbonate paragenesis of Mississippi Valley-type deposits suggests that the carbonate paragenesis in these deposits may be related to the thermal alteration of organic matter. By competing with fluoride for Mg, bicarbonate ions from decarboxylation of organic matter and dissolution of carbonates may break the MgF^+ complex, form the $MgHCO_3^+$ complex, and thereby liberate fluoride to trigger the precipitation of fluorite. (Authors' abstract)

SPYCHER, N.F., 1987, Boiling and acidification in epithermal systems: Numerical modeling of transport and deposition of base, precious and volatile metals: PhD dissertation, Univ. Oregon.

Boiling and acidification of hydrothermal waters are important processes that lead to mineral precipitation in geothermal systems. In this study, numerical models of boiling and acidification are applied to a chemical system that contains base, precious and volatile metals. The numerical model incorporates simple newly-developed methods to account for heat balance and for the non-ideal behavior of gaseous H_2O, CO_2, CH_4, and H_2. Also, the stoichiometry and stability of As and Sb thiosulfides at elevated T are evaluated, and included in an internally consistent set of thermodynamic data for As and Sb aqueous species, minerals and gases.

Equations derived from a quadratic virial equation in P are fitted to published P-V-T and solubility data to yield values of fugacity coefficients and enthalpies for several pure and mixed gases. The method presented here is limited to moderate P-T ranges and cannot represent accurately P-V-T data close to the critical region. This virial equation treatment yields simple analytical expressions that are suitable for multicomponent equilibrium calculations.

Least square fits and multicomponent equilibrium computations on selected solubility data of Sb_2S_3 and As_2S_3 in sulfide solutions indicate that the most probable stoichiometries of Sb and As thiosulfides are $H_2Sb_2S_4$, $HSb_2S_4^-$ and $Sb_2S_4^{2-}$, and $H_3As_3S_6$, $H_2As_3S_6^-$ and $HAs_3S_6^{2-}$. All three As species, but only $HSb_2S_4^-$ are stable within the pH range of typical geochemical systems.

The virial equation treatment and thermodynamic data for As and Sb is used with existing software to simulate boiling and acidification of a Broadlands-type geothermal water that contains base, precious and volatile metals. The results indicate that boiling leads to the precipitation of base metals, electrum and sulfosalts, and that acidification precipitates Au-rich electrum or pure Au, along with sulfosalts and enargite at low T. Below 100°C, acidification precipitates orpiment and stibnite. Upon boiling, Hg fractionates into the gas phase, but As and Sb stay in the aqueous phase. In cooling of a dry gas phase, Sb stays in the gas down to 220°C where stibnite sublimates, and As stays to 130°C where realgar sublimates. Gas condensation below 100°C results in the precipitation of cinnabar. (Author's abstract)

SPYCHER, N.F. and REED, M.H., 1988, Fugacity coefficients of H_2, CO_2, CH_4, H_2O and of H_2O-CO_2-CH_4 mixtures: A virial equation treatment for moderate pressures and temperatures applicable to calculations of hydrothermal boiling: Geochimica Cosmo. Acta, v. 52, p. 739-749. Authors at Dept. Geol. Sci., Univ. Oregon, Eugene, OR 97403, USA.

Equations derived from a quadratic virial equation in P, with virial coefficients expressed as a function of T, are fitted to published P-V-T and solubility data to yield values of second and third virial coefficients for pure and mixed gases. These coefficients are not virial coefficients *sensu stricto* and are used to compute fugacity coefficients of pure H_2, H_2O, CO_2 and CH_4, and of mixed H_2O, CO_2 and CH_4, and to estimate enthalpies for these gases. For H_2, the P-T range of application is from 25 to 600°C and up to 3000 bars, and for CH_4, from 16 to 350°C and up to 500 bars. For H_2O and CO_2, two P-T ranges are considered: below 350°C, up to 500 bars, and from 450 to 1000°C, up to 1000 bars. The method presented here is limited to the P-T range of the fitted experimental data, and cannot represent accurately P-V-T data close to the critical region.

This virial equation treatment yields simply analytical expressions that are suitable for multicomponent equilibrium calculations. Examples of equilibrium calculations between aqueous and gas phases show that ideal mixing of real gases is a sufficient approximation for modeling boiling in geothermal and epithermal systems. However, non-ideal mixing has to be considered for aqueous-gas systems at P much higher than the saturation P of pure water. (Authors' abstract)

See also previous item. (E.R.)

SRIKANTAPPA, C., ASHAMANJARI, K.G., NARASIMHA, K.N.P. and RAITH, M., 1988, Retrograde, charnockite-gneiss relations in southern India (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 144-146 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 170-171). First author at Dept. Geol., Univ. Mysore, Manasagangotri, Mysore 570 006, India.

Fluid inclusion studies and geochemical investigations carried out on serial samples from charnockite to gneiss indicate following features: (1) There is a gradual decrease in density of CO_2-rich fluids from 1.073 to 0.821 g/cm^3. (2) Many sections of the gneisses show an almost complete absence of fluid inclusions suggesting decrepitation. (3) Mixed CO_2-H_2O inclusions were present. (4) Low salinity (2-14 wt.% NaCl eq.) bi-phase H_2O-rich inclusions (0.925-0.725 g/cm^3) suggest rehydration during retrogression. (5) Fluid inclusion studies in quartz pegmatites indicate presence of low density CO_2-rich inclusions (0.840-0.659 g/cm^3) as well as H_2O-rich inclusions (0.900-0.525 g/cm^3). (E.R.)

SRIKANTAPPA, C., BASAVARAJAPPA, H.T. and JANARDHAN, A.S., 1988, Fluid inclusions in charnockites from the Biligirirangan Hills, Karnataka, India (abst.): Terra cognita, v. 8, p. 255. First author at Dept. Geol., Univ. Mysore, India.

Charnockites of the Biligirirangan Hills are medium- to coarse-grained, dark greenish grey colored rocks of granitic to granodioritic composition. The rocks exhibit granoblastic mosaic texture with the mineral assemblage quartz-plagioclase-orthopyroxene ± clinopyroxene-garnet-biotite. Retrogressive mineral assemblages consisting of bluish-green hornblende-epidote and symplectitic intergrowths of biotite + quartz, are noticed in samples collected towards the western margins of the BR Hills. This zone represents a major N-S trending shear. Based on the mineral chemistry of the charnockitic assemblage, a metamorphic T & P of 750°C and 7.5 kb is obtained.

Preliminary fluid inclusion studies on charnockites show the following types of fluid inclusions: 1) CO_2, high density (1.06 to 1.09 g/cm^3), 2) CO_2, low density (0.86 g/cm^3), 3) "exploded" inclusions, 4) H_2O, low salinity (4 to 6 wt% NaCl eq.)/high T ($\approx$ 320°C), and 5) H_2O-NaCl high salinity (35 wt% NaCl eq.)/low T (<230°C).

CO_2-rich fluid inclusions showing higher densities of 1.09 g/cm^3 correspond closely with the P-T data derived from the mineral chemistry and thus appear to be syn-metamorphic. Occurrence of "exploded" inclusions suggests polymetamorphic nature for the area studied.

The low density CO_2-rich inclusions (0.86 g/cm^3) and H_2O-NaCl-bearing aqueous inclusions are related to retrograde metamorphism, during major shear deformation in the area. (Authors' abstract)

SRIKANTAPPA, C. and NARASIMHA, K.N.P., 1988, Retrogression of charnockites in Moyar shear zone, Tamil Nadu, India: Geol. Soc. India Memoir 11, p. 117-124. Authors at Dept. Geol., Univ. Mysore, Mysore 570 006, India.

Within the Moyar shear zone, enderbitic charnockites of the Nilgiri hills show evidence of shearing and retrogression. Field and petrographic studies suggest alteration of garnet, orthopyroxene and plagioclase to chlorite, greenish-blue hornblende and epidote. Fluid inclusion studies indicate a change in the early high density carbonic stage (0.99 g/cm^3) to late low density (0.74 g/cm^3) CO_2-rich inclusions and addition of aqueous fluids during retrogression. A minimum entrapment T of ~350°C at P of ~2 kb is estimated based on fluid inclusion data. (Authors' abstract)

SRIVASTAVA, D.C. and ENGELDER, Terry, 1988, A mechanism for the development of fault-bend folds: Strike veins in the Bellefonte Dolomite, central Pennsylvania (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A57-A58. Authors at Dept. Geosci., Pennsylvania State Univ., University Park, PA 16802, USA.

If the folds of the central Appalachian foreland fold-thrust belt have developed as fault-bend folds then individual beds moving through the hinges of these fault-bend folds should show evidence of folding and then unfolding. The Bellefonte Dolomite contains such evidence where the earliest joints are calcite-filled veins in the strike orientation. In outcrop these veins are planar, are contained within beds, and exhibit a distinct plumose surface morphology which was later mantled with an insoluble residue characteristic of stress solution. In thin section these strike veins are associated with stress solution seams and exhibit curvilinear boundaries. After stress solution the veins reopened by a crack-seal mechanism during which the successive openings were filled chronologically by syntaxially grown fine fibrous calcite and coarse stretched crystals along with blocky calcite. Despite developing normal to the regional compression direction these veins initially opened in tension below the neutral fiber of fold, were later compressed as indicated by the insoluble residue, and finally opened again below a netural fiber.

These strike veins are cut by later cross-fold veins and the latter show sharp-rectilinear boundaries. The cross-fold veins are filled by coarse and blocky calcite which is symmetrically bordered by thinner zones of fine grained calcite with wall rock inclusion bands. In addition, some cross-fold veins also show stretched crystal fibers running from wall to wall. Distinct overprinting relationships establish that strike veins are older than cross-fold veins. This is supported by the heating-freezing data on several hundred aqueous fluid inclusions revealing higher salinity of brines and also higher T during the development of strike veins as compared to cross-fold veins. (Authors' abstract)

STAKES, D.S. and VANKO, D.A., 1988, Penetration of fluids into oceanic layer three: Preliminary evidence from the 500m deep section of ODP site 735 (abst.): EOS, v.69, p.463. The first author at Dept. Geol. Sci., Univ. of SC., Columbia, SC. 29208.

There are abundant two-phase (L+V) fluid inclusions in hydrothermal/metamorphic plagioclase and amphibole. There are also restricted occurrences of 3-phase fluid inclusions (L+V+halite dxls) indicating local generation of saline brines. This is consistent with the occurrence of Cl-apatite and Cl-amphibole, the latter of which is also enriched in Fe, and preliminary oxygen isotopic data. (From the authors' abstract)

STALDER, H.A., 1987 - See Peters et al., 1987, this volume. (E.R.)

STARKEY, R.J., Jr., 1988, Low-grade metamorphism of the Karmutsen volcanics, Vancouver Island, British Columbia: PhD dissertation, Univ. Wyoming, Laramie, WY, USA, 164 pp (177 ?).
Indexed under "Fluid Inclusions." (E.R.)

STARUKHINA, L.V. and KRUZHANOV, V.S., 1988, Spontaneous motion of liquid inclusions in a crystal near its surface: Sov. Phys. Crystallogr., v. 32, no. 4, p. 629-630. Authors at State Univ., Khar'kov, USSR.

Stretching of inclusions near the surface is asymmetrical, resulting in more dislocations between inclusion and surface; the inclusion then moves toward the surface at rates of 10^{-9} cm•sec^{-1} (at constant T). (E.R.)

STAUDACHER, Th. and ALLEGRE, C.J., 1988, Noble gases in glass samples from Tahiti: Teahitia, Rocard and Mehetia (abst.): Chem. Geol., v. 70, p. 41. Authors at Lab. Geochimie & Cosmochimie, I.P.G., 4 Place Jussieu, 75252 Paris Cedex 05, France.

We analyzed a suite of ten high vesicular glass samples from Teahitia and Rocard Seamounts and Mehetia Islands, SE from Tahiti.

The glasses show a vesiculation between 4.6 and 47 vol %. Samples from Rocard Seamount show typical MORB-like ^{4}He/^{3}He ratios of about 90,000 and ^{20}Ne/^{22}Ne and ^{21}Ne/^{22}Ne ratios up to 11.8 and 0.055 respectively. The Ne ratios perfectly plot into the MORB Ne isotopic correlation (this meeting). Furthermore, one Rocard glass shows a high ^{40}Ar/^{36}Ar ratio of 15,260 as usually observed in MORB glasses. Thus we exclude a significant lower mantle component for Rocard Seamount.

One of the samples from Rocard Seamount and samples from Teahitia show a particularity. The ^{4}He/^{3}He ratios in these samples range between 123,000 and 231,000 and are probably due to either mixing with subducted crustal material and/or sediments or mass fractionation through massive He loss by diffusion from the high vesicular samples after eruption.

Samples from Mehetia Island show low ^{4}He/^{3}He ratios of 64,000 and ^{40}Ar/^{36}Ar ratios of 510 and 670. Such is in agreement with mixing between lower and upper mantle material. Being highly vesicular (29.1%) we cannot decide whether or not the glasses from Mehetia have lost He by diffusion as we propose for example for Teahitia and if the initial ^{4}He/^{3}He ratios of Mehetia have been even smaller than 64,000.

Finally we observed deep sea water contamination in some samples from Rocard Seamount, based on Ne and Ar isotopes. (Authors' abstract)

STAUDE, J.-M., SELVERSTONE, Jane and MORTEANI, Giulio, 1988, Chemical and kinetic changes associated with synmetamorphic ductile shearing, Tauern Window, eastern Alps (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A332. First author at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138.

Ductile shearing along vertical shear planes in the SW Tauern Window, Austria, has transformed Hercynian tonalite into Gar-Chl-Staur schist. The transition from unaltered to recrystallized rock occurs within 1 m in a shear zone (SZ) 8-20 m wide by several km long. The SZ truncates both Hercynian fabrics and Mesozoic rocks, indicating an Alpine age. Porphyroblasts within the SZ overprint the shear fabric and yield final equilibration conditions of 550-600°C and ~7 kbar, indicating that shearing occurred at or near the Alpine thermal peak and during initial decompression from P(max) = 10.5 kbar.

Large garnets occur only in the most hydrated horizons and contain myriad oriented submicroscopic fluid inclusions. We suggest that garnet growth was facilitated by initial grain-size reduction during shearing and pervasive influx of fluids. Near the SZ margins, garnet nucleation rates dominated overgrowth rates, but the reverse is true in the hydrated center of the SZ. (From the authors' abstract by H.E.B.)

STAVRAKEVA, D.A. and KASTCHIEVA, E.P., 1988, Microliquation in the glasses of magmatic rocks (abst.): Chem. Geol., v. 70, p. 90. Authors at Higher Inst. Chem. Tech., 1756 Sofia, Bulgaria.

Microliquation has been established in some polycomponent systems with technical function. The mechanism of crystallization of the melts has been related to the microliquation heterogeneity.

The microstructure of various glasses obtained from magmatic rocks with chemical composition ranging from ultrabasic to acidic rocks has been studied through electron microscopy. A microheterogeneity with origin of liquation in all glasses studied is found.

Microliquation heterogeneities are related to the crystal chemistry, namely: The possibility of Al^{3+} in the melt at a given concentration of Al_2O_3 (10-25%) to be both in the tetrahedral (AlO_4) and octahedral (AlO_6) coordination and the severe differences in the ionic radius of Fe^{2+}, Fe^{3+}, Mg^{2+}, Ca^{2+}, Na^{1+}, K^{1+} which determine the incompatibility in the structure and the absence of isomorphous substitution between all cations.

An experiment has been done in order to explain Bowen's scheme for crystallization of magmatic silicate melts in two independent lines - orthosilicate, chain - and band silicate, layer silicate from one side and tectosilicate (framework) from the other side. (Authors' abstract)

STEGEN, R.J. and BEATY, D.W., 1988, Constraints on genetic models for the Aspen district (Colo.), derived from fluid inclusion, stable isotope, and geologic studies (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A278. First author at P.O. Box 1482, St. George, UT 84770.

Recent multidisciplinary research has constrained possible genetic models for the Zn-Pb-Ag-Ba ores of the Aspen district. Age of Mineralization: There are no unequivocal geologic relationships in the Aspen district to constrain the age of mineralization. Source of Sulfur: The early and late sulfur-bearing minerals were derived from a sedimentary source ($\delta^{34}S$ barite = +12.3 to +12.9; sulfides = -11.5 to -22.9), and sulfides in the middle of the paragenesis probably came from an igneous source ($\delta^{34}S$ near zero). Source of Lead: The Pb isotopic composition of galena from Aspen ore is similar to that of galena from Gilman and Leadville (suggesting an igneous source), and is dramatically different from that at Mt. Sherman. Transport Mechanism: The early barite was transported by an aqueous fluid with $\delta^{18}O$ = -1 to +1 (inferred basinal brine), and the porphyry was altered by a fluid with $\delta^{18}O$ = +5 to +10 and δD = -40 to -60 (inferred magmatic water). The former fluid had a mean salinity of about 3 wt. % eq. NaCl; the salinity of the latter fluid was not measured. Temperature of Formation: The T of ore deposition is estimated on the basis of both fluid inclusion and sulfur isotope fractionation data to be about 250-280°C.

The following mineralization model appears to best account for all of the data: Laramide uplift of the Sawatch Range resulted in formation of the Castle Creek and associated faults along its west margin. A large batholithic mass was concurrently emplaced within central Colorado with

Aspen lying on its northwest fringe. A steep geothermal gradient developed, causing fluids to migrate from evaporitic rocks deposited in the Central Colorado Trough towards the rising Sawatch Range. Igneous-related fluids, sulfur and Pb apparently were involved in at least part of the hydrothermal history. Fluid flow was localized by Laramide structures then channeled through stratabound brecciated beds in the Leadville Limestone. (Authors' abstract)

STEGENA, Lajos, 1988, Paleogeothermics, Handbook of terrestrial heat-flow density determination; with guidelines and recommendations of the International Heat Flow Commission, R. Haenel et al., eds.: Kluwer Acad. Publ., Netherlands, p. 391-419.

Indexed under "Fluid Inclusions." (E.R.)

STEIN, C.L. and KRUMHANSL, J.L., 1988, A model for the evolution of brines in salt from the lower Salado Formation, southeastern New Mexico: Geochim. Cosmo. Acta, v.52, p.1037-1046. First author at Sandia Nat. Lab., Albuquerque, NM 87195, U.S.A.

Fluid inclusions were collected from a bedded salt horizon in the lower Permian Salado Formation in the Delaware Basin, southeastern New Mexico. The sampling horizon, at a depth of ≈645 m, consists primarily of recrystallized halite, with thin layers of anhydrite. Other trace minerals, dispersed throughout the salt, include quartz, polyhalite, gypsum, K-feldspar, magnesite, and clays. Large fluid inclusions (up to several mm on an edge) are common in the halite; in addition, bands of microscopic (<10μm) fluid inclusions are present as P ("chevron") structures in fragments of unrecrystallized salt. We sampled 109 large inclusions by individual extraction of the fluids, which were analyzed for Ca, Mg, K, Na, Cl, Br, and SO_4. The chemistry of the inclusion fluids and the associated mineralogy suggest that these brines represent Permian seawater that has undergone evaporation and subsequent modification by diagenetic reactions, dominated by the alteration of calcium sulfate to polyhalite and magnesite formation. The range of fluid inclusion compositions suggests a significant departure from a simple seawater evaporation model. Other brines from the same horizon in the Salado Formation were sampled and analyzed for the same elements as the fluid inclusions, and differed significantly from them primarily by the depletion of Mg relative to K. The association of these brines with argillaceous and/or anhydritic halite containing a suite of authigenic minerals (quartz, magnesite, and Mg-rich clays) suggests that these are intergranular brines with compositions determined over a much longer time scale than that required by the fluid inclusions. The principal reactions affecting intergranular brine chemistry are dehydration of gypsum, dewatering of detrital clays, and uptake of Mg during clay diagenesis. Overall, the observed variation in brine compositions implies that, if large-scale hydrologic circulation is occurring in the Salado halite, the time scale is limited by the rate required for low-T silicate diagenesis. (Authors' abstract)

STEIN, C.L. and McTIGUE, D.F., 1988, Thermal migration of fluid inclusions in halite: A field experiment and model results (abst.): EOS, v. 69, p. 1446. First author at Geochem. Div. 6233, Sandia National Lab., Albuquerque, NM 87185.

Liquid-filled inclusions in salt can migrate up an imposed thermal gradient by dissolution at the hot inclusion wall and reprecipitation at the cold wall. A large-scale field experiment was conducted over a period of about three years at the Waste Isolation Pilot Plant (WIPP) in which an array of electric heaters was emplaced in the Permian salt. The heat flux to the borehole walls was approximately 200 W/m^2; the wall T reached about 140°C, and the T gradient at the wall was of the order of 40°C/m. Such gradients are about 1/100 those typically achieved in the laboratory, and on which most previous observations are based.

Post-test petrographic analysis of salt within 20-25 cm of the borehole shows abundant evidence of inclusion migration toward the heat source. The largest undeformed inclusions within this interval are of the order of 50 µm on a side. Above this size, inclusions are deformed into elongate "tubes" with aspect ratios of about 10:1 and ~500-1000 µm long. Assuming that this length represents the minimum path of an inclusion, we infer average migration velocities of the order of ~10^{-11} m/s (~1 µm/day). Both the observed minimum size for motion and the inferred velocity are in good agreement with the theoretical and laboratory results of Olander, et al. (J. Appl. Phys., 53 (1982), 669-681).

The alteration of polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$) to anhydrite in the heated salt indicates a possible source of a portion of the inclusion fluids due to release of structural water. (Authors' abstract)

STERNER, S.M., HALL, D.L. and BODNAR, R.J., 1988a Post-entrapment compositional changes in fluid inclusions: Experimental evidence for water diffusion in quartz (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A100. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blackburg, VA 24061.

Abundant evidence suggests FI can stretch or shrink in response to differential P encountered following trapping. Previous experiments have shown that at 600°C under conditions of rapid deformation inclusions in quartz undergo dramatic density changes while still maintaining a constant chemical composition. Thus, while the densities recorded by these inclusions are no longer meaningful, they are still compositionally representative samples of the fluid(s) 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). Resultant inclusions are neither volumetrically <u>nor</u> compositionally representative of the fluids present during initial trapping.

In the present investigation, FI having initial compositions of 25 and 57 wt. % NaCl were formed by hydrothermally healing fractures in quartz at 3 kb and 600 or 800°C in the presence of the appropriate brine. These inclusions were then reequilibrated for 7 days at 1.5 kb and 825°C - conditions creating internal overpressures of ~1.5-2.5 kb in the inclusions. Elevated vapor bubble Th in all reequilibrated inclusions indicate that substantial density decreases have occurred. Similarly, elevated salt dissolution T (Tm(NaCl)) in the reequilibrated inclusions indicate that salinities have increased relative to their initial values due to preferential loss of water. For example, inclusions initially trapped at 3 kb and 800°C from a 57 wt. % brine had initial Tm(NaCl)'s of 480 ± 3°C. Following reequilibration, inclusions in this sample display a range of Tm(NaCl) from 480 to 530°C corresponding to a range in salinity from 57 to 64 wt. % NaCl. To insure that the elevated Tm(NaCl)'s were not solely the result of the increased volume of the water-rich vapor phase, a sample was prepared from a 57 wt. % brine at 1.5 kb and 825°C. Tm(NaCl)'s recorded in these inclusions (485 ± 3°C) were only slightly greater than those described above for inclusions trapped at 3 kb and 800°C.

Inclusions in each reequilibrated sample display a strong negative correlation between salinity and inclusion volume. This observation is consistent with the 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. (Authors' abstract)

STERNER, S.M., HALL, D.L. and BODNAR, R.J., 1988b Synthetic fluid inclusions. V. Solubility relations in the system NaCl-KCl-H_2O under vapor-saturated conditions: Geochim. Cosmo. Acta, v. 52, p. 989-1005. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24051, USA.

Vapor-saturated solubility relationships in the system NaCl-KCl-H_2O have been determined by experimentally synthesizing fluid inclusions in quartz in the presence of known brine compositions and then measuring the dissolution T of halite and/or sylvite dxl within the inclusions using a microscope equipped with a heating stage. These data, along with other literature values have been used in a stepwise multiple regression routine to generate a series of equations describing vapor-saturated solubility relations within 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 fluid inclusions approximated by the NaCl-KCl-H_2O system.

For the NaCl-H_2O binary system, the ternary halite field expression reduces to

$$\text{Wt.\% NaCl} = 26.242 + 0.4928\Psi + 1.42\Psi^2 - 0.223\Psi^3 + 0.04129\Psi^4 + 0.006295\Psi^5 - 0.001967\Psi^6 + 0.0001112\Psi^7 \ (\Psi = \text{T°C}/100 \text{ where } 0.1 \le \text{T°C} \le 801\text{°C})$$

which describes halite solubilities along the three-phase halite + liquid + vapor (H + L + V) curve. Similarly, sylvite solubilities along the three-phase sylvite + liquid + vapor (S + L + V) curve are described by the equation

$$\text{Wt.\% KCl} = 21.886 + 20.28\Psi - 9.603\Psi^2 + 4.078\Psi^3 - 0.8724\Psi^4 + 0.09174\Psi^5 - 0.003776\Psi^8 \ (\Psi = \text{T°C}/100, \text{ where } -10.7° \le \text{T°C} \le 770\text{°C}).$$

Solubility data obtained from synthetic fluid inclusions are in good agreement with recently published data for the KCl-H_2O and NaCl-H_2O binary systems but are a variance with some earlier works. (Authors' abstract)

Note that coefficient"s" for the halite field in column 1 of Table 2 is incorrect. The coefficient should have a negative sign in front of it, i.e., - 0.00488294 (personal comm., S.M. Sterner; printed in Geochim. Cosmo. Acta, v. 52, p. 2549, 1988). (E.R.)

STEVENSON, J., MANCUSO, J., FRIZADO, J., TRUSKOSKI, P. and KNELLER, W., 1988, Solid pyrobitumen in veins, Panel Mine, Elliot Lake, Ontario, (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A118. First author at Bowling Green Univ., Bowling Green, OH 43403.

Globular blebs of solid pyrobitumen occur in veins in open stopes and drifts in the Panel Mine in the Elliot Lake Uranium District, Ontario. The veins fill fractures in the 2.2 billion year old Matinenda Formation. The blebs are small (1-10 mm) and free-form varying in shape from round to disc, twisted or elongate. The surfaces are shiny and permeated with vesicles. These blebs are 80% carbon with H/C ratio 0.57, reflectivity (mass Ro) 0.91%, and $\delta^{13}C$ of -33 per mil (PDB).

Quartz crystallized first in the fractures followed by a first generation pyrite. Blebs of pyrobitumen are attached to the surfaces of quartz and pyrite and are encased by sepiolite. A second generation of large (5-15 mm) pyrite contains inclusions of sepiolite and pyrobitumen. Pyrrhotite and galena were deposited with and/or after second generation pyrite. Large (5-20 cm) calcite crystals enclose pyrobitumen and all other minerals in the fractures. This paragenetic sequence suggests a natural origin; however, Kaiman and Horwood (1976) concluded that similar carbonaceous blebs (thucholite) in the Milliken Mine (Elliot Lake District) were formed by the agglomeration and polymerization of carbon particles from the exhaust of diesel mining equipment. Further evidence accrued in our study suggests that pyrobitumen blebs in the Panel Mine are the result of natural migration and maturation of Precambrian petroleum.

Blebs of similar morphology were reported from fracture fillings in the Cambrian Bonneterre Formation from the Magmont West Mine on the Viburnum Trend, Missouri, and the Ordovician Trenton Formation in Wyandot County, Ohio. Both are considered to have been formed from locally derived oil that was polymerized in the fractures. (Authors' abstract)

STOCKEY, J.R. and McLELLEN, Eileen, 1988, Correlation of fluid inclusion populations from the Henderson Augen Gneiss, Brevard Zone, Rosman, N.C., with strain gradients and fluid flux during deformation (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A332-A333. First author at Dept. Geol., George Washington Univ., Washington, DC 20052.

Multiple populations of fluid inclusions, separable by geometry in oriented sections, are present in a transect across the Brevard Zone. Five types of inclusion populations have been identified based on geometric orientation of planes or trails, size and shape of inclusion, relative proportion of vapor/liquid and sequence. Presence/absence and variation in these populations support the thesis that increasing strain from protolith Henderson Augen Gneiss to mylonite is a result of increasing stress gradient as the Brevard Zone is approached, while the occurrence of ultramylonite zones is due to complete recrystallization in the presence of a fluid flux. The progressively sheared gneiss retains the original inclusion population, albeit modified, in addition to developing two new types, while the ultramylonite retains no direct evidence of the protolith inclusions. The fluid inclusion populations and field evidence such as variation in grain size, deformation texture and phenocryst size, shape and occurrence, support the same spatial distribution of these processes previously suggested by variations in mineralogy, whole rock geochemistry and stable isotopes. Decrease in overall grain and phenocryst size and increase in deformation textures corresponds to modification of the original inclusion population and addition of new ones as the strain gradient increases cross the Brevard Zone. The highy localized fluid flux is documented by sudden changes in mineralogy, whole rock geochemistry, $\delta^{18}O$ values, and in this study by the complete destruction of all previous fluid inclusion populations and the development of new population. (Authors' abstract)

STÖCKHERT, B., HUCKE, M., RÖSNER, G. and HARBOTT, W., 1988, Experimental deformation of low melting point crystalline material under the polarizing microscope - Experiences with a new Means type apparatus (abst.): Terra cognita, v. 8, p. 78.

STOPLER, Edward, 1988, Degassing of magmas: Constraints from experimental determinations of volatile solubilities and studies of volcanic glasses (abst.): Chem. Geol., v. 70, p. 41. Author at Div. Geol. & Planet. Sci., Caltech, Pasadena, CA 91124, USA.

Solubilities of CO_2 and H_2O have been determined experimentally for basaltic and rhyolitic melts over a range of P. Infrared (IR) spectroscopy was used to measure concentrations of carbonate, hydroxyl, and CO_2 and H_2O molecules in glasses quenched from vapor-saturated melts.

Concentrations of CO_2 and H_2O in volcanic glasses have also been measured, mostly by IR spectroscopy, and interpreted in light of experimentally determined solubilities. Some important conclusions: (1) 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). (2) Dissolved CO_2 and H_2O in obsidian clasts in pyroclastic rocks and lava flows from the Mono Crates, CA, generally decreased as the eruption proceeded. Results for obsidians in the pyroclastic deposits suggest that the parent magma was relatively rich in CO_2 (perhaps from degassing of basalts under-plating the high-level silicic magmatic system) and that degassing approached closed system behavior. Hydrogen isotopic data suggest a transition to open system degassing late in the eruptive sequence, coinciding with a transition from explosive to quiescent eruptions. (3) Analyses of glass inclusions from phenocrysts from the plinian and ash-flow deposits of the Bishop Tuff, CA, by IR spectroscopy indicate that H_2O was enriched and CO_2 depleted upward 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 liquid enriched in H_2O and depleted in CO_2 similar to the plinian inclusions. Assuming vapor saturation, P of entrapment of the inclusions are typcially 1.5-2.5 kbar. (Author's abstract)

STOLPER, Edward and HOLLOWAY, J.R., 1988, Experimental determination of the solubility of carbon dioxide in molten basalt at low pressure: Earth & Planet. Sci. Letters, v. 87, p. 397-408. First author at Div. Geol. & Planet. Sc., California Inst. Tech., Pasadena, CA 91125, USA.

We report the first measurements of CO_2 solubility in molten basalt at P comparable to those at which submarine basalts erupt. A basalt from the Juan de Fuca ridge was equilibrated with CO_2-rich vapor at 1200°C, 100-1500 bar for up to four hours. After quenching, the glass was analyzed for dissolved carbonate ions by infrared spectroscopy. No forms of dissolved CO_2 other than carbonate were detected. CO_2 solubility is roughly a linear function of P at these low P. The experimentally determined solubility differs from previous estimates based on CO_2 concentrations of submarine glasses, on CO_2 solubilities in basaltic liquids at significantly higher P, and on CO_2 concentrations of glasses equilibrated with H_2O-CO_2 vapor. Our results are compatible with those obtained previously at higher P on a molten Kilauea tholeiite only if there is a significant positive dependence of carbonate solubility on T. CO_2 contents of mid-ocean ridge glasses measured by infrared spectroscopy are generally higher than would be expected based on solubilities at the hydrostatic P for the water depths from which the glasses were recovered, but the lowest dissolved CO_2 contents agree with the experimentally determined solubilities. We propose that submarine glasses with low CO_2 contents were quenched from magmas that were able to degas because they rose slowly from depth. The common occurrence of glasses with dissolved CO_2 contents in excess of the experimentally determined solubility suggests they were quenched from magmas that ascended too rapidly to degas fully. In conjunction with our solubility data, the highest CO_2 contents allow minimum estimates of depths to magma chambers. Depths of >km beneath the ridge are indicated for the East Pacific Rise at 21°N, in agreement with geophysical constraints. (Authors' abstract)

STONE, J., WICKHAM, S.M., and O'NIONS, R.K., 1988, Helium and carbon in crustal fluids: Constraints on granulite production by mantle-derived CO_2 (abst.): EOS, v.69, p.467.

STOUT, M.Z., CRAWFORD, M.L. and GHENT, E.D., 1987, Pressure-temperature and evolution of fluid compositions of Al_2SiO_5-bearing rocks, Mica Creek, British Columbia, in light of fluid inclusion data and mineral equilibria (abst.), in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 758. First author at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Alberta, Canada T2N 1N4.

Metamorphosed pelitic rocks from Mica Creek, British Columbia, contain sillimanite, kyanite with minor fibrolite and andalusite-bearing quartz pods. Mineral compositions were used to infer peak P-T conditions and fluid compositions in equilibrium with the solid phases. Fluid inclusions in three schist samples prove to be good indicators of conditions affecting those rocks during and after peak metamorphic conditions. In samples from two localities fluid inclusions from schist and quartz-rich segregations have densities appropriate to the peak metamorphic conditions. The observed aqueous fluid compositions (low salinity with ≃ 12 mole % dissolved CO_2) agree with calculated $X(H_2O)$ values near 0.85, based upon paragonite-quartz-albite-Al_2SiO_5 equilibria. The fluids unmixed as the schists were uplifted and cooled; fluid inclusions trapped during this stage outline a solvus in the CO_2-H_2O-NaCl system. A later influx of fluids containing CH_4 and N_2 accompanied formation of andalusite-bearing plagioclase-rich segregations. Other low density fluid inclusions from this outcrop are very saline aqueous inclusions and the significantly lower Te and Tm of the inclusions suggest the presence of salts other than NaCl. The restricted association of andalusite-bearing pods and low density fluids suggest a localized but pervasive fluid influx during uplift. Preservation of high density fluid inclusions during uplift and erosion, coupled with evidence for unmixing of H_2O- and CO_2-rich fluids on the solvus, provide constraints on the P-T uplift path. (Authors' abstract)

STRUCKMEYER, Heike and BROWNE, P.R.L., 1988, Application of the vitrinite reflectivity method to samples from the Wairakei-Tauhara and Ohaaki geothermal fields: Proc. The 10th New Zealand Geothermal Workshop, Univ. Auckland Geothermal Inst., 1988, p. 251-255.

STURCHIO, N.C., KEITH, T.E.C. and MUEHLENBACHS, K., 1988, The dynamics of silica deposition in fractures: Oxygen isotope ratios in hydrothermal silica from Yellowstone drill core Y-13: Geother. Resources Council, Transactions, v. 12, p. 305-312. First author at Argonne Nat'l. Lab., CMT-205, Argonne, IL 60439.

The $\delta^{18}O$ values of 22 samples of hydrothermal chalcedony and quartz from Y-13 drill core range from -7.5 to -1.3‰. Most samples could not be in mineral-water isotopic equilibrium under present conditions. Fluid inclusion Th in quartz indicate precipitation at or above T measured during drilling. Most silica appears to have precipitated from water enriched in ^{18}O relative to present thermal water. Inferred ^{18}O enrichments are too large in many cases to be explained by boiling and steam separation. The apparent ^{18}O enrichment in thermal water may represent a transient dynamic effect that occurs when new fractures open, as disequilibrium increases and the local system is temporarily perturbed. This interpretation is consistent with the observed sequence of mineral deposition of $\delta^{18}O$ within individual fractures. (Authors' abstract)

SUGAKI, A., 1988, Tin mineralization of polymetallic ore deposits in Bolivia (abst.): Mining Geol., v. 38, no. 1, p. 81 (in Japanese).

SUGAKI, Asahiko and KITAKAZE, Arashi, 1988, Tin-bearing minerals from Bolivian polymetallic deposits and their mineralization stages: Mining Geol., v. 38, no. 5, p. 419-435. First author at 4-30-503 Kadan, Sendai 980, Japan.

Various kinds of tin-bearing minerals, such as cassiterite, stannite, kesterite, franckeite, hocartite, teallite, cylindrite, rhodostannite, canfieldite, incaite and potosiite occur from polymetallic deposits in Eastern Cordillera of Bolivian Andes. These deposits, called Bolivian type polymetallic deposits, were formed by xenothermal mineralization related to Miocene igneous activities. The mineralization stages are generally divided into six as follows: I: quartz-tourmaline, II: quartz, III: quartz-pyrite, IV: sulfide, V: sulfosalt and VI: sulfate-phosphate stages. Cassiterite principally occurs in the quartz-tourmaline (I), quartz (II) and quartz-pyrite (III) veins. Stannite and kesterite appear in the sulfide (IV) and sulfosalt (V) veins. Meanwhile, tin-bearing sulfosalt minerals, such as franckeite, hocartite, teallite, cylindrite, rhodostannite and canfieldite are found commonly in the sulfosalt (V) vein in small amount. Th and NaCl eq. concentration of fluid inclusions in quartz at each stage of the mineralization are I: 260° to 510°C and 18.5 to 55.4 wt%, II: 250° to 405°C and 23.4 to 26.0 wt%, III: 250° to 400°C and 4.4 to 19.7 wt%, IV: 230° to 350°C and 1.5 to 10.6 wt%, and V: 190° to 300°C and 0.4 to 5.4 wt%, respectively. The Th, salinities and sulfur fugacities at each stage decrease as a whole with progressing the mineralization stage. Sulfur fugacity values at the III, IV and V stages are 10^{-15} to 10^{-9} atm., and 10^{-16} to 10^{-9} atm., respectively. (Authors' abstract)

SUGAKI, A., KOJIMA, S. and SHIMADA, N., 1988, Fluid inclusion studies of the polymetallic hydrothermal ore deposits in Bolivia: Mineral. Deposita, v. 23, p. 9-15. First author at Inst. Mineral., Petr. & Econ. Geol., Tohoku Univ., Sendai 980, Japan.

Th and salinity were determined for fluid inclusions in mostly quartz and partly sphalerite, cassiterite, and barite from the 28 tin-polymetallic ore deposits in Bolivia. Generally, the Th and salinities of these fluid inclusions are comparatively high for ore deposits formed by cassiterite mineralization, such as Morococala and Avicaya in the Oruro district, frequently indicating a T higher than 300°C and salinity higher than 20 eq. wt% NaCl. Particularly, it is quite possible that in deposits associated with the W-Bi and tourmaline mineralizations such as Viloco and Caracoles have been produced by such high-T hypersaline fluid ranging up to 500°C and 56 eq. wt% NaCl, similar to the porphyry copper type. This feature reveals that the hydrothermal fluid related to the Sn-W-Bi mineralization may be of magmatic origin. Th for the Pb-Zn deposits with no tin minerals are low, mostly ranging 170°-300°C. At the Avicaya-Bolivar mining area in the Oruro district as well as at the Tasna and Chocaya-Animas mining areas in the Quechisla district T gradients consistent with the zonal distributions of ore minerals were confirmed. (Authors' abstract)

SUGIYAMA, T., TAKATORI, K. and UEDA, A., 1988, Stable isotopic study of fluid inclusion of quartz from Sado mine (abst.): Mining Geol., v. 38, no. 1, p. 67-68 (in Japanese).

SUKHOV, L.G. and APLONOV, V.S., 1988, Thermobarogeochemical model of formation of copper-nickel ores: Dokl. Akad. Nauk SSSR, v. 298, no. 5, p. 1189-1193 (in Russian). First author at Central-Arctic Geol.-Prospecting Expedition "Sevmorgeologiya," Noril'sk, USSR.

The paper presents results of the decrepitometric studies (T 20-700°C, decrepitometer D-1) of 107 pyrrhotite, cubanite and chalcopyrite specimens from massive ores of the Oktiabr'skoe deposit, Noril'sk region. The T of ore formation is suggested on the basis of the regression analysis of the obtained data. (A.K.)

SUSHCHEVSKAYA, T.M., 1988, Geochemistry of the ore-forming fluids of deposits of the cassiterite-silicate association, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 179-190 (in Russian).

SUSHCHEVSKAYA, T.M., BANNIKOVA, L.A. and USTINOV, V.I., 1987, Physico-chemical and isotopic data on the formation of typical tin deposit of cassiterite-silicate type, in Models of Ore-Forming Systems, V.I. Sotnikov, ed.: "Nauka" Press, Novosibirsk, p. 152-162 (in Russian; English abstract by T.M. Sushchevskaya).

The purpose of the paper was to investigate the role of $f(O_2)$ and pH in hydrothermal solutions, as factors controlling the formation of Sn deposits. The study was undertaken using the Solnechnoye deposit (Komsomolsk region, Far East of USSR), which was rather typical for Sn deposits of so-called cassiterite-silicate formation, tourmaline type (Lugov et al., 1976).

The deposit is situated in a large submeridional fracture structure in Jurassic sedimentary terrigeneous rocks. The deposit is composed of a plate of quartz-tourmaline metasomatic rocks, surrounded by quartz-sericite and sericitized host sandstones and shales, and cut by quartz-cassiterite and quartz-sulfide veins and veinlets. The sequence of mineral assemblages is: (1) quartz-tourmaline (QT), (2) quartz-tourmaline-cassiterite-arsenopyrite-(QCs), (3) quartz-pyrrhotite-pyrite-chalcopyrite-stannite (QS), (4) quartz-carbonate-fluorite-pyrite.

The results of fluid inclusion studies for T, bulk salt and gaseous composition and of isotopic studies for $\delta^{18}O$ of quartz and cassiterites, carbonates, and also of analyses organic compounds (table*) gave us the possibility to draw the scheme of formation of the Solnechnoye deposit.

During the preore quartz-tourmaline stage the $f(O_2)$ values were rather low to provide the necessary predominance of Sn(IV) compounds in the mineral-forming solutions; as a result cassiterite did not crystallize. The sulfide minerals of Sn had not formed because of high T and rather low concentration of S(II) in the solutions.

The beginning of cassiterite formation was connected with increase of $f(O_2)$ and pH of solutions and accompanied by the change in carbon isotopic composition of carbonates and change in ^{18}O of the fluid. The successive deposition of sulfide associations was characterized by $f(O_2)$ decrease and increase in S(II) concentration in the solutions. It caused the deposition of sulfostannates instead of cassiterite, because of Sn(II)/Sn(IV) ratio increase.

The causes of $f(O_2)$ changing in ore-forming solutions were examined with the help of calculations of redox interactions between the reduced compounds of carbon and sulfates, taking place during mixing the solutions with corresponding physicochemical characteristics. Oxygen isotopic data are in accordance with the conclusion of mixing of fluids of different history of formation in the zone of ore deposition. (Authors' abstract)

*This table does not appear in the Russian original. The original contains plots of SnII/SnIV at 300°C, for various pH; compositions of inclusions in preore quartz, ore quartz, and cassiterite, in terms of K-Na-(Ca + Mg) and $Cl-HCO_3-F$; gas chromatographic analyses for H_2O, CO_2, CH_4, CO, N_2, H_2 for 35 samples of quartz, from the preore quartz-tourmaline, the ore assemblage cassiterite-tourmaline-arsenopyrite-chalcopyrite-pyrite, and "productive quartz;" isotopic composition of carbon (20 samples); and plots of fO_2-pH; and $X(CH_4)$ - $X(SO_4)$ (initial). (E.R.)

Mineral association T°C	Cl/HCO_3 1)	CO_2/CH_4 1)	lg $f(O_2)$ 2)	$^{13}C(CO_2)$ ‰ PDB 3)	$^{34}S(H_2S)$ 4)	Bitumens Hydrocarbons 5)	$^{18}O(H_2O)$ ‰ SMOW 6)	C_SII,m
QT 450-350	10-5	10^0	-31	-2.3	-3.8	0.6	8.3 - 5.0	10^{-3}
QCs 350-300	5-1	10^2-10^3	-33- -34	-7.2	-3.8- -1.6	1.2 - 2	5.3 - 3.4	10^{-3}
QS 300-250	1-0.5	10^0-10^2	-35- -36	-8- -11.7	-0.8- -0.5 1.7- 2.3	4	2.3 - 2.1	$10^{-1.7}$

1) calculated from leachate analyses of fluid inclusions
2) calculated from bulk chromatographic data
3) calculated from analyses of carbonates and measurements of $\delta^{13}C$ of CO_2 extracted from inclusions
4) calculated from analyses of sulfides
5) analyzed extracts from mineral associations
6) calculated from $\delta^{18}O$ of minerals

SUSHCHEVSKAYA, T.M., KOKINA, T.A., KORSAKOVA, N.V. and KNYAZEVA, S.N., 1988, Concentration of sulphide, S(II), during the formation of cassiterite-silicate deposits: Dokl. Akad. Nauk SSSR, v. 300, no. 1, p. 213-215 (in Russian; translation by T.M. Sushchevskaya).

Concentration of sulfides in fluid inclusions solutions (C_SII) in quartz samples from several deposits of USSR was determined using a potentiometric technique with an ion selective electrode. Extraction of the inclusion fluids was carried out by grinding clean crushed (0.25-0.5 mm) quartz samples (0.5-4.0 gr) in an agate mortar in NaOH solution (0.1-1.0 m). It was found that the rate of sulfide oxidation was very low, so it was possible to perform all the procedures in the presence of atmospheric air, and also without adding reducing agents.

The quartz samples analyzed were separated from successive mineral assemblages: pre-ore quartz-tourmaline (1), ore quartz-cassiterite-tourmaline-arsenopyrite (2), main sulfide quartz-pyrite-pyrrhotite-chalcopyrite, sometimes with stannite (3), and post-ore quartz-pyrite-carbonate, from the Solnechnoye, Prydorohznoye, and Festivalnoye deposits, Komsomolsk ore region. The quartz samples of Mushiston deposit (Middle Asia region) was analyzed for determining the conditions of formation of stannite, which predominated over cassiterite at this deposit. It was found that deposition of the main productive mineral association (quartz-cassiterite-arsenopyrite) at 300°C took place from the solutions with $C_S \geq 10^{-3}$ m, and deposition of sulfide associations (arsenopyrite-chalcopyrite-stannite) correlated with C_SII increase up to $\geq 10^{-2}$ m. (Authors' abstract)

SUSTAVOV, O.A., 1988, The diagnosis, conditions of formation, and prospecting value of submicroscopic fluid inclusions, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 156-162 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 408. (E.R.)

SVOREN', I.M., 1988, Forms of occurrence of hydrogen in certain solid materials of different origin according to the physicochemical model of hydrogenation of solid bodies, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 95-103 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 408-409 (possibly). (E.R.)

SWITZER, C.K., LAING, W.P. and RUBENACH, M.J., 1988, The Proterozoic Starra Au + Cu ironstone deposit - Syntectonic mineralization in a folded early regional zone of decollement (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 212-214. Authors at Geol. Dept., James Cook Univ. of North Queensland, 4811.

P fluid inclusions within quartz contain CO_2 and crystals of KCl, Fe and Ca chlorides. Th are ~200°C and Tm KCl are ~400°C. The mineralizing fluid was clearly very saline; it was not a CO_2-dominated fluid as found in the Western Australian Archaean ironstone Au deposits.

The fluid is at least partly metamorphic in origin. However its highly saline nature requires a specific source. This might be (i) saline fluids from basinal sequences in the fractured upper plate of an extensional tectonic setting; (ii) metamorphic fluids buffered by saline evaporitic units within the metamorphosing sequence; or (iii) magmatic fluids in a saline porphyry-style system. There are strands of evidence for each of these. (From the authors' abstract)

TABAKSBLAT, L.S. and RAPOPORT, A.M., 1988, Metals in brines from deep horizons in the Kama region: Geokhimiya, 1988, no. 1, p. 138-141 (in Russian; translated in Geochem. Int'l., v. 25, no. 8, p. 119-121). Authors at Sverdlovsk Mining Institute.

Includes analyses for Mn, Ni, Co, Cu, Zn, Pb, Cd, Sr, Li, Rb, Cs, W, Ta, Sb, Sc and REE. (E.R.)

TAKAGI, H., FUJINO, T. and KUROKAWA, K., 1988, Investigations on hydrothermal activities using fluid inclusion geothermometry in the Otake and Hatchobaru geothermal fields: Int'l. Symp. on Geothermal Energy, Kumamoto and Beppu, Japan, Nov. 10-14, 1988, p. 39-42. First author at West Japan Engrg. Consultants, Inc., Watanabe-dori, Fukuoka, Japan.

Th of fluid inclusions in hydrothermal minerals such as quartz, anhydrite and calcite from wells in the Otake and Hatchobaru geothermal fields have been measured. Th from wells drilled in the producing zone distribute along a narrow range a little inside of the boiling point curve. The lowest value at each depth is quite close to the present T of fluid conduits and reservoirs.

The reservoir T in the Otake geothermal field is estimated to be 190-200°C at the producing level (300-500 m below surface) and 250-280°C at the producing level (1,000-1,500 m below surface) in the Hatchobaru geothermal field. The distribution of Th from wells drilled in the reinjecting zone has a wide range and show a bimodal distribution. The lowest value of the T peak agrees well with the present T, whereas the value of the higher T peak appears to be equal to the original reservoir T.

The T contour map at the producing level in the Otake geothermal field obtained from the fluid inclusion geothermometry shows that the geothermal fluid comes up from the south at a steep angle and forms a reservoir with T of 190-220°C. In the Hatchobaru geothermal field, the T contour map reveals that a high T zone above 270°C strikes east to west and breaks towards the north at southeast of the power plant. (Authors' abstract)

TAKENOUCHI, S., 1988a, Extraction technique in gas analysis of fluid inclusions -- Comparison of crushing and decrepitation methods (abst.): Mining Geol., v. 38, no. 1, p. 68 (in Japanese; translation courtesy S. Takenouchi).

Two types of technique for the extraction of fluid inclusion contents were compared. Crushing method using a stainless steel vacuum vessel and an alumina ball (32 mm in diameter) with fused silica glass instead of quartz generated 0.011-0.025 cm^3 of N_2 (at STP) in vacuum and 0.045 cm^3 of CH_4 besides N_2 in CO_2 atmosphere. N_2 is generated supposedly by the abrasion between the metal wall of vessel and quartz, and CH_4 is probably by the reduction of CO_2 by the newly formed fresh surface of quartz by crushing. The amounts of N_2 and CH_4 generated by crushing are relatively large compared to the amounts of gases released from fluid inclusions in such samples as the Tertiary epithermal Au-Ag quartz veins which have few small fluid inclusions. Decrepitation method has more advantages than the crushing method. Gas compositions of fluid inclusions determined by the combination of decrepitation and gas chromatography were reported. (Author's abstract)

TAKENOUCHI, S., 1988b, Fluid inclusion study at Okuaizu geothermal area: Int'l. Symp. on Geothermal Energy, Kumamoto and Beppu, Japan, Nov. 10-14, 1988, p. 35-38. Author at Fac. Engrg., Univ. Tokyo, Tokyo 113, Japan.

It is inferred from the results of fluid inclusion study that the geothermal activity at the Okuaizu area has not changed appreciably since the deposition of vein-filling minerals. In most cases, Th of fluid inclusions correspond fairly well to the measured well T laterally and vertically. In the central part, well and inclusion T increase up to ~300°C at levels of ~1,000 m below the sea level, but in the peripheral zone, they drop to ~150°C, especially in the western block of the Takizawagawa fault. Coincidence of the thermal structures of the present and former activities represents that the geothermal activity at the Okuaizu area is at the apex or increasing, and that the area is a preferable area to develop the geothermal power plants. (Author's Concluding Remarks)

TAKENOUCHI, Sukune, 1988c, Fluid inclusion studies of selected epithermal gold deposits and the Doroyu geothermal system of Japan: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 237-244. Author at Dept. Min. Dev. Engrg., Univ. Tokyo, Tokyo 113, Japan.

Fluid inclusions from epithermal Au deposits, hydrothermally altered siliceous rocks and a terrestrial geothermal system were studied. Th of fluid inclusions in quartz from the Nansatsu-type epithermal Au deposits range mainly between 165°C and 240°C, but the T of hydrothermal fluids which formed the Kawarage siliceous rocks distribute in a wider range and boiling of fluids is commonly indicated. There is a good correlation between the Th of fluid inclusions and present well T within the high-T zone of the Doroyu geothermal system. This study indicates a complex and variable thermal history for the shallow portions of hydrothermal systems. (Author's abstract)

See also Takenouchi, 1986b, Fluid Inclusion Research, v. 19, p. 436-437. (E.R.)

TAKENOUCHI, Sukune, 1988d, Fluid inclusion study of the Doroyu geothermal area, Akita: J. Geothermal Res. Soc. Japan, v. 10, no. 4, p. 321-338 (in Japanese; English abstract). Author at Dept. Min. Dev. Engrg., Univ. Tokyo; Hongo, Bunkyo, Tokyo 113.

More than 2,000 fluid inclusions in 34 samples of calcite, quartz and wairakite collected from drill cores of the Doroyu geothermal area, Southern Akita, were studied in order to know the relation between the Th of fluid inclusions and measured well T. Geology of the Doroyu area is mainly composed of the Pre-Tertiary basement, Miocene andesitic and dacitic formations, late Miocene lacustrine sediments and Quaternary volcanic formations. Geothermal fluids are found near the boundaries between the basement and Tertiary formations and along the NW-SE step-faults which separate the southern Oyasudake upheaval zone and northern Kijiyama subsided zone. The studied drill holes were selected to represent two vertical sections, the one of which cuts through the western low-T zone of the area, and the other runs through the eastern high-T zones.

Calcite veinlets are abundant in the high-T zone and the Th of fluid inclusions in the calcites change concordantly with the present well T. In the low-T zone, S fluid inclusions in quartz grains of dacitic tuffs were mainly used for T determination owing to the scarcity of calcite veinlets. In general, ranges of Th in the low-T zone are much higher than the present well T. The present fluid inclusion study revealed that high T hydrothermal fluids were once active in the western zone but the activity is waning at present, and that the activity of the eastern zone is at the apex or on the way to increase. (Author's abstract)

TAKEUCHI, Koichi, 1988, Mode of occurrence of the Arakawa No. 5 vein, tellurium-bearing silver-gold deposit of the Kushikino mine, Kagoshima Prefecture: Mining Geol., v. 38, no. 1, p. 49-56 (in Japanese; English abstract). Author at Nagasaki Prefectural Ceramic Res. Inst., Iseki-go 2240, Hasami-cho, Nagasaki 859-37, Japan.

Tellurium-bearing ore has been produced from the Arakawa No. 5 vein of the Kushikino mine. The mine consists of many epithermal Au-Ag vein type deposits which are related to the late Miocene to early Pliocene volcanism. Ore minerals constituting the "ginguro" (Ag-bearing sulfide-sulfosalts band) ore are galena, hessite, sphalerite, chalcopyrite, pyrite and electrum. Other Ag-minerals such as naumannite and polybasite which appear commonly [in such assemblages] in this mine are not found. Sphalerite in the "ginguro" ore contains about 50 mol% CdS at its maximum. The Th of fluid inclusions are relatively high, ranging from 260° to 310°C. (From the author's abstract, H.E.B.)

TAN, L.P. and KIRWIN, D.J., 1988, Gold-copper mineralization at Chinkwashih, northeast Taiwan (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 389-390. First author at Geol. Dept., National Taiwan Univ., Taipei.

Limited data indicate Th of 160°C - 300°C with two peaks at 200° and 250°C. The enargite-dominant mineralization is considered to be an early high T phase possibly related to an underlying porphyry-Cu type intrusive. (From the authors' abstract)

TANER, H., WILLIAM-JONES, A.E., and WOOD, S.A., 1988, A fluid inclusion study of molybdenum mineralization in the Preissac-Batholith, Quebec (abst.): GAC/MAC Program with Abstracts, v.13, p.A122. Authors at Dept. of Geol. Sci., McGill Univ., Montreal, Quebec H3A 2A7.

Mo-Bi mineralization occurs in quartz-K-feldspar-muscovite veins surrounded by early albitic and later K-feldspar alteration haloes in leucoadamellite of the Archaen, Preissac batholith. The veins contain three main types of fluid inclusions: LV aqueous inclusions, LLV carbonic inclusions, and L and LV halite-bearing aqueous inclusions. Aqueous inclusions display 3 distinct salinity groupings with peaks of 5, 18, and 28 wt.% NaCl eq. respectively. All three aqueous inclusion types and the aqueous phase in carbonic inclusions show low Te, typically less than -70°C, indicating the presence of salts other than NaCl, KCl, and $CaCl_2$ in solution. The occurrence of lithium mineralization in pegmatites in the Preissac Lacorne Batholith and the low Te of the system $LiCl-H_2O$ (-76°C) suggest that LiCl may be a component of the fluids. Aqueous inclusions have Th(L) between 300°C and 375°C. The carbonic phase in carbonic inclusions generally melts between -56.6°C and -58°C indicating that it consists largely of CO_2. Carbonic inclusions Th(L) between 300°C and 330°C. Halite-bearing aqueous inclusions have Tm NaCl(Th) of ≈ 170°C. A model is proposed in which early albitic alteration is related to high T moderate salinity aqueous fluids of possible orthomagmatic origin, K-feldspar alteration to more evolved aqueous fluids, and Mo mineralization to the effervescence of CO_2 from these fluids as a consequence of decreasing T and/or P. (Authors' abstract)

TANGER, J.C., IV, 1988, An equation of state for H_2O-NaCl solutions (abst.): EOS, v. 69, p. 1480. Author at Dept. Chem., Univ. California, Berkeley, CA 94720.

An equation of state for H_2O-NaCl solutions is presented which permits close description of the available composition data for the entire vapor-liquid coexistence surface at T from 250 to 600°C. The equation is given by

$$P = P_{H_2O}(T,\tilde{d}) + A_1Y + A_2Y^2 + A_3Y\tilde{d},$$

where A denotes a T-dependent, empirical coefficient, Y represents mole ratio, and $\tilde{d}$ stands for the reduced density of H_2O in soluton. The reduced density is given by $\rho_{soln}(100 - wt\%)/(100\rho_{c,H_2O})$, where ρ represents density in g cm^{-3} and ρ_{c,H_2O} stands for the critical density of pure H_2O.

Predicted P-T surfaces for various thermodynamic properties at vapor-liquid saturation P are discussed and geochemical implications are explored. Special attention is given to the compositions and thermodynamic properties of coexisting vapors and liquids at conditions close to the critical point of H_2O. Near the critical point, calculated isothermal and isobaric coexistence curves reveal local maxima and minima in vapor phase solubility. In addition, the thermodynamic properties of the coexisting phase can change substantially with small changes in P and T.

By using the properties of 3.2 wt% NaCl solutions to approximate those of seawater, this equation of state allows estimation of the thermodynamic properties of seawater in mid-ocean hydrothermal systems. As an exmple application, calculated enthalpies and entropies are used to investigate T and composition changes resulting from two-phase and single-phase adiabatic expansion of hydrothermal seawater.

Extension of the equation of state to permit description of the available solution volume data for NaCl to 600°C, 4 kb and salt saturation is also presented. Calculation of isochores and fluid inclusion filling T is straightforward because the solution P is related to the P of H_2O in solution by means of a simple expansion in solution density and composition. P of H_2O in solution can be readily obtained using the equation of state for H_2O from Haar et al. 1984 which is available as a computer code. (Author's abstract)

TANGER, J.C., IV and HELGESON, H.C., 1988, Calculation of the thermodynamic and transport properties of aqueous species at high pressures and temperatures: Revised equations of state for the standard partial molal properties of ions and electrolytes: Am. J. Sci., v. 288, p. 19-98.

TANGER, J.C., IV and PITZER, K.S., 1988, Recent advances in the calculation of thermodynamic properties for aqueous electrolytes at supercritical H_2O conditions (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Authors at Dept. Chem., Univ. California, Berkeley, CA 94720.

Two recently developed independent models for prediction of the standard state thermodynamic properties of aqueous electrolytes have greatly expanded the range of P and T for which we can estimate these properties. Together these models provide close description of the available data for standard state volumes and heat capacities and permit estimation of thermodynamic properties from 0 to 1000°C and any P up to 5 kilobars. Available data for solution heat capacities and compositions of coexisting vapors and liquids in the system NaCl-H_2O have a complex P-T dependence in the vicinity of the critical point of H_2O. Nevertheless, this data can be closely represented using a recently proposed equation of state. In addition, this equation of state permits close description of available composition data for the entire NaCl-H_2O vapor-liquid coexistence surface from 250 to 550°C. By using the properties of 3.2 wt.% NaCl solutions to approximate those of seawater, this equation of state can be used to estimate the thermodynamic properties of seawater at T and P characteristic of mid-ocean, hydrothermal systems. (Authors' abstract)

TANGUY, J.C. and CLOCCHIATTI, R., 1984, The Etnean lavas, 1977-1983: Petrology and mineralogy: Bull. Volcanol., v. 47-4, no. 2, p. 879-894. First author at Univ. Paris 6, Lab. de Pétrol. Minéral. & Lab. Géomag., 94107 Saint-Maur des Fossés Cedex, France.

The chemical composition of glass inclusions interpreted as trapped liquids suggests that olivine and magnetite crystallize first and are followed by pyroxene and plagioclase. The early appearance of olivine has been determined by optical thermometry to about 1170°C, soon followed by plagioclase and pyroxene (1160-1140°C). Pre-eruptive crystallization further progresses until 1073°C which is the field-measured T at the lava vent. Then, the appearance and composition of microlites (and outer rims of phenocrysts) depend upon the cooling rate of the samples (water quenching or natural cooling). Electron microprobe analyses of chlorine and sulphur have been performed on crystal trapped and groundmass glasses. Sulphur ranges from an initial content of 1500 ppm to 400 ppm in residual glass, leading to an average sulphur emission of 1500 tons/day (3000 t/d SO_2), as estimated from the volume of erupted lava. (From the authors' abstract by E.R.)

TAYLOR, B.E., 1988, Degassing of rhyolitic magmas: Hydrogen isotope evidence and implications for magmatic-hydrothermal ore deposits, <u>in</u> Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 33-49. Author at Geol. Survey of Canada & Dept. Geol., Univ. Ottawa, Ottawa, Ontario, Canada.

Recognition of degassing systematics is important to understanding the origin of certain magmatic-hydrothermal ore deposits. For example, pronounced degassing of epizonal magmas was associated with Mo (and other) porphyry systems. In such systems, the hydrogen isotope shift which accompanied magma degassing may be utilized as a chemical marker to study the mass transport of rock- and ore-forming elements in the vapor phase. Hydrogen isotope evidence for degassing in non-ore-bearing magmatic systems may suggest that the timing of vapor-saturation and/or composition of the ore-related magma are principal factors in the development of some ore deposits. (From the author's abstract by H.E.B.)

TAYLOR, B.E. and GERLACH, T.M., 1988, Carbon isotopic composition of volcanic gases from early episodes of the 1983 east rift zone, Kilauea volcano, Hawaii (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A112. First author at Geol. Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8, Canada.

The 113 measurements reported for the isotopic composition of carbon in CO_2 from summit fumaroles at Kilauea volcano give a mean value for $\delta^{13}C$ of -3.35 per mil (relative to the PDB standard) with a standard error of ± 0.03. Recent degassing models for the summit magma chamber indicate that plutonic degassing of up to 97% of the CO_2 in the parental magma supplied to the summit chamber provides the source of the summit fumarole CO_2. The summit data together with the experimental fractionation factor determined for carbon isotopes between CO_2 gas and basaltic melt give a predicted $\delta^{13}C$ for the carbon remaining in magma after plutonic degassing of -7.7 with a propagated standard error of ± 0.1. We have tested this pediction on nine gas samples collected at $T > 900°C$ from lava that underwent plutonic degassing in the summit chamber before extrusion in the early episodes of the 1983 east rift zone eruption. These samples give a $\delta^{13}C$ of -7.8 with a standard error of ± 0.2, which agrees with the predicted value. (Authors' abstract)

TAYLOR, Derek, 1988, Thermal expansion data XIII. Complex oxides with chain, ring and layer structures and the apatites: British Ceram. Trans. J., v. 87, p. 88-95.

TAYLOR, R.G. and POLLARD, P.J., 1988, Pervasive hydrothermal alteration in tin-bearing granites and implications for the evolution of ore-bearing magmatic fluids, in Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 86-95. Authors at Dept. Geol., James Cook Univ. North Queensland, Australia.

Selective pervasive alteration of various types is widely recorded in granites associated with tin and other rare-metal mineralization. The high-silica, F-rich granites of the Herberton tin field are characterized by the ubiquitous development of a suite of hydrothermal alteration minerals. The alteration is essentially grain boundary controlled and consists of an early potassic stage overprinted by albitization, sericitization, and argillization. This sequence exhibits a close relationship with the paragenetic sequence of fracture-related tin mineralization. The intensity of alteration varies within and between individual plutons but is clearly post-magmatic in character. A fluid inclusion study of an intensely albitized pluton indicates that the fluids responsible for both the selective pervasive and fracture-related alteration are essentially identical with a wide range in T and salinity (up to 60 wt % eq. NaCl and maximum Th of 500°C to 600°C). Oxygen isotope studies are generally consistent with a model of early magmatic fluids with later meteoric/connate input.

A single evolving fluid could provide the 2 to 5 phases of mineralization of generally declining T and salinity that are often reported within individual tin districts. In this sense the major control upon mineralization type and distribution is via fracture evolution rather than by derivation from pulsations of fluids from deeper sources. This general mechanism is consistent with the morphology of tin systems, and would also explain why fracture controlled mineralization frequently cuts, and apparently postdates the suspected mineralizing pluton. Meteoric/connate input is likely to develop in later-phase mineralization as the evolving fracture system links with surface fracture system. (From the authors' abstract by H.E.B.)

TAYLOR, T.R., 1988, Carbonate cementation and dissolution in Miocene sandstones from Corsair trend, offshore, Texas (abst.): AAPG Bull., v. 72,

p. 253. Author at Shell Dev. Co., Houston, TX.

Middle Miocene sandstones occur in Picaroon field (Corsair trend; offshore Texas Gulf Coast) at depths of approximately 13,000-17,000 ft (3.9-5.1 km). These deltaic sandstones contain evidence of the following sequence of diagenetic events: (a) precipitation of chlorite coatings on detrital grains; (b) partial dissolution of feldspar; (c) quartz cementation; (d) calcite cementation; (e) dissolution of calcite cement; (f) ankerite cementation. The reservoir quality of the sandstones is largely a function of porosity enhancement due to calcite dissolution.

Calcite cement was emplaced at depths of approximately 3,000 to 8,500 ft. The calcite has $^{87/86}$Sr values of 0.70833 to 0.70865, eliminating coeval (~ 15 m.y.) sea water and marine carbonate (0.70873-0.70885) as a potential source. The $^{87/86}$Sr composition of calcite cement is consistent with mass transfer of calcite from older marine sources to younger sediments. Fluid inclusion measurements indicate that ankerite cement formed at T of approximately 120°-145°C (11,000 to 14,000 ft). Oxygen isotope modeling predicts that at these depths shales would expel waters with $\delta^{18}O$(SMOW) of +5 to +8 during smectite-illite conversion. Ankerite ($\delta^{18}O$(PDB) = -7.8) would be in isotopic equilibrium with the predicted waters at the T derived from fluid inclusions. Ankerite cements have relatively radiogenic $^{87/86}$Sr ratios (~ 0.7097) which are consistent with their formation from shale-derived fluids. Calcite dissolution occurs between the precipitation of calcite and ankerite. It is therefore concluded that calcite cement dissolution occurred at burial depths of 8,5000 to 11,000 ft (95°-120°C). Although the cause of calcite dissolution is unknown, these T overlap with the range in which high concentrations of dissolved organic acids have been reported in Gulf Coast formation waters. (Author's abstract)

TESORIERO, A.J. and KNAUTH, L.P., 1988, The distribution of trace water around brine leaks in the Avery Island salt mine; implications for the natural migration of water in salt: Nuclear & Chem. Waste Mgmt., v. 8, no. 3, p. 189-197.

Indexed under "Fluid Inclusions." (E.R.)

THEODORE, T.G., CZAMANSKE, G.K., KEITH, T.E.C. and OSCARSON, R.L., 1988, Bismuth minerals associated with placer gold, Battle Mountain mining district, Nevada (extended abst.): U.S. Geol. Survey Circular 1035, p. 72-74.

Placer Au nuggets contain abundant, euhedrally terminated quartz crystals draped with Au. At room T, fluid inclusions in the quartz are liquid-rich and vapor-rich, suggesting boiling. Th of liquid-rich fluid inclusions range from 150 to 355°C (mean, 265°C). The lack of fluid inclusions containing dms suggests that the bulk of the placer Au was not genetically associated with high-T saline stages of nearby vein, breccia pipe, and skarn formation. Rather, the nuggets containing bismuth minerals are thought to have been derived from lower T stages in Au-bearing skarn that are known to contain significant late-stage Bi minerals. Some nonmineralized skarns apparently are high-T deposits and show abundant liquid-vapor homogenization of highly saline (30 to 60 wt. % NaCl eq.) fluid inclusions in the range from 500 to 600°C. (From the authors' abstract by E.R.)

THOMAS, A.V., BRAY, C.J. and SPOONER, E.T.C., 1988, A discussion of the Jahns-Burnham proposal for the formation of zoned granitic pegmatites using solid-liquid-vapor inclusions from the Tanco pegmatite, S.E. Manitoba, Canada: Trans. Royal Soc. Edinburgh: Earth Sci., v. 79, p. 299-315. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

Jahns and Burnham (1969) proposed that the internal evolution of zoned granitic pegmatites could be explained by crystallization from water-saturated melts which evolved to produce systems with a melt plus a separate aqueous fluid. Examination of microthermometric properties, chemical compositions and gas contents of solid-liquid-vapor inclusions from a number of the zones of the Tanco rare element granitic pegmatite places constraints on fluid evolution within the framework of the crystallization history of the pegmatite, and contributes to an examination of the Jahns-Burnham proposal.

Initial crystallization at Tanco was from the wall rock inwards, producing the relatively unfractionated wall zone (potassium feldspar-quartz-albite-muscovite). Textural evidence and an upward increase in the level of geochemical fractionation, indicate that much, <u>but not all</u>, of the subsequent crystallization of the pegmatite was from the base upwards. Inclusions trapped by wall zone and metasomatic wall rock tourmaline indicate that the pegmatite was intruded as a 2-phase alumino-silicate melt/fluid mixture at ~720°C, with an initial fluid composition of ~98 mol% H_2O (containing 2 eq. mol% NaCl) and <2 mol% CO_2 (containing <5 eq. mol% CH_4). These observations indicate that both melt and fluid were present from the start of crystallization (Jahns & Burnham 1969), but show that CO_2 and dissolved salts were important additional components of the fluid phase. The bulk of the pegmatite then crystallized in the range 600-470°C from melts and fluids with continued low levels of CO_2 (2-3 mol.%) and approximately constant salinity (~7 eq. wt.% NaCl dissolved in the aqueous phase). Crystal-rich inclusions, which may represent trapped aluminosilicate melts, are present throughout pegmatite crystallization down to as low as ~262°C. The final stages of crystallization resulted in the formation of the beryl fringe at 291 ± 33°C and the lower part of the quartz zone at 262 ± 29°C. By the later stages the fluid had cooled through an H_2O-CO_2-dissolved salt solvus resulting in H_2O-CO_2 phase separation. Gas chromatographic analysis of the fluid components in the vug quartz, beryl fringe and lower part of the quartz zone shows that the inclusions contain H_2O, CO_2, CH_4, H_2, CO, Ar, and trace C_2H_6 in the beryl fringe. Measured CH_4:CO_2 ratios of 0.0060 (± 0.0015) for the beryl fringe (twenty crushes on five samples) and 0.0042 (± 0.0021) for the quartz zone (thirty crushes on six samples) yield fO_2 estimates of 1×10^{-36} and 2×10^{-38}, respectively, which are just above QFM at these T. (Authors' abstract)

Includes a 2-page appendix on the techniques used for thermometry, gas chromatography, and SEM. (E.R.)

THOMAS, A.V. and SPOONER, E.T.C, 1988a Occurrence, petrology and fluid inclusion characteristics of tantalum mineralization in the Tanco granitic pegmatite, southeastern Manitoba, <u>in</u> Recent advances in the geology of granite-related mineral deposits, R.P. Taylor and D.F. Strong, eds., Special Vol. 39, Canadian Inst. Min. & Metal., p. 208-222. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada.

The (1440 m by 820 m by 100 m) Tanco granitic pegmatite, southeastern Manitoba, [Canada,] was the major hard rock Ta producer in the world from pre-production reserves of 2,071,350 tons at 0.216 Ta_2O_5 until cessation of operation in December 1982. Ta-oxides were extracted from the eastern banded aplites (ETO), western high grade ore (WTO) and, to a lesser extent, a lepidolite unit.

Although the WTO and ETO are very different in appearance their mineralogical associations and fluid inclusion characteristics are similar with the exception that beryl is more abundant and muscovite more lithian in the WTO. H_2O-CO_2 fluid inclusions in both ETO and WTO (type b) have similar properties. Both have mixed H_2O:CO_2 ratios, and Th behavior of the ETO banded aplite inclusions indicate that this variability is due to the trapping of a H_2O-CO_2 fluid which was undergoing phase separation. CO_2 fusion points in both are depressed by 0.5°C to 1.0°C indicating the presence of other components miscible in the CO_2. The salinity of the aqueous phase in both instances is 8 to 9 eq. wt. % NaCl and initial fusion T for the ice phase indicate the presence of divalent salts. Comparison of these fluids with those in other inclusions so far studied in Tanco suggests that these fluids may be peculiar to the Ta mineralized zones. However, at this stage, it is not possible to say exactly what the nature of the liquids responsible for Ta-mineralization was.

Since, H_2O-CO_2 phase separation has been demonstrated for the ETO banded aplite, beryl fringe and Quartz Zone the H_2O-CO_2 Th are equal to Tt. The estimates for the Tt of the ETO lithologies derived in this way are in descending order, banded aplite (316 ± 50°C, n = 49), beryl fringe (291 ± 37°C, n = 33), Quartz Zone (265 ± 30°C, n = 76). These data have been analyzed using a Mann-Whitney nonparametric statistical test. They have been found to represent significantly different populations. This cooling sequence is consistent with the depositional sequence inferred independently from field observations. An estimate for the T deposition of the wodginite in the banded aplites based on this study is therefore approximately 320°C. (From the authors' abstract by H.E.B.)

THOMAS, A.V. and SPOONER, E.T.C., 1988b Fluid inclusions in the system H_2O-CH_4-NaCl-CO_2 from metasomatic tourmaline within the border unit of the Tanco zoned granitic pegmatite, S.E. Manitoba: Geochim. Cosmo. Acta, v.52, p.1065-1075. First author at Dept. of Geo., Univ. of Toronto, Toronto, Ontario, Canada M5S 1A1.

Fluid inclusions from the tourmaline phase of alteration of the footwall amphibolite from the Tanco zoned granitic pegmatite lie in the system H_2O-CH_4-NaCl-CO_2. These inclusions contain a L and V phase at room T and develop a second L phase on cooling in the range -77 to -95°C: the second L and the V are methane. Isochores for inclusions showing V phase (CH_4) homogenization were constructed from the equations of JACOBS and KERRICK (1981). The intersections of these isochores with the univariant melting curves for methane clathrate hydrates give estimates of salinity for the inclusions of between 7 and 10 eq wt.% NaCl, which are lower than those derived from measurement of the depression of the melting point of ice; a result consistent with salt exclusion by clathrate. The bulk composition of the fluid is estimated to be 91 mol.% H_2O, 6 mol.% CH_4, 2 equiv. mol.% NaCl and <1 mol.% CO_2. Total Th have a mean value of 371°C±36°C (1σ; n=91). Variation of Th behavior between Th(H_2O) phase and critical homogenization is compatible with the composition of the inclusions being on the steep H_2O-rich limb of the H_2O-CH_4-NaCl solvus. The data suggest that the consolute T for a H_2O-CH_4 mixture with ≈2 mol.% salt should be ≈400-420°C. Extrapolation up the bulk isochore to 2700-2900 bars trapping P gives a TE of ≈720-780°C; which is an estimate of the intrusion T of the Tanco pegmatite.

Calculation of f_{O_2} from the bulk inclusion composition gives values near WI at these conditions which is unreasonably low for fluids derived from the pegmatite, which were probably between QFM and HM. The metasomatic fluids may have resulted from fluid mixing in the wall rock immediately adjacent to the pegmatite. The fluid derived from the pegmatite, a H_2O-CO_2 fluid, introduced the B necessary to form tourmaline in the amphibolite. On the other hand it is suggested that CH_4±H_2O may have been derived from a metamorphic fluid which formed in equilibrium with graphite at lower oxygen fugacities at ≈400°-600°C and which was present in the wall rock at the time of pegmatite emplacement. Supporting evidence is provided by pegmatite wall zone fluids with higher CH_4 (≈5 equiv. mol.% in CO_2) than the bulk of the pegmatite H_2O-CO_2 fluids (0.8 mol.% in CO_2), suggesting marginal fluid contamination. (Authors' abstract)

THOMAS, Rainer and TISCHENDORF, Gerhard, 1988, Variscan to Late-Variscan magmatism and metallogenesis in the Erzgebirge: Temperature-time-salinity modelling: Z. geol. Wiss (Berlin), v. 16 no. 6, p. 557-559 (in English).

On the basis of thermometric measurements on melt inclusions in quartz of granites and fluid inclusions in various minerals in connection with age data Thomas and Leeder (1986; Fluid Inclusion Research, v. 19, p. 441-442) as well as Thomas and Tischendorf (1987; Fluid Inclusion Research, v. 20, p. 380) determined an exponential functional relationship between T and time. This paper presents a second approximation, corrected by the "elimination of spurious data." The plot of Th vs. time is then differentiated graphically to obtain T changes with time and hence thermal pulses. The original data set apparently involves melt inclusions in the older intrusions and aqueous inclusions in the younger ore deposits. (E.R.)

THOMASSIN, J.H., CASSEAULT, S. and IIYAMA, J.T., 1988, Early stages of the hydrothermal alteration of a basalt glass (abst.): Terra cognita, v. 8, p. 78.

THOMPSON, A.B. and CONNOLLY, J.A.D., 1988, Generation and migration of deep crustal fluids during regional metamorphism (abst.): Chem. Geol., v. 70, p. 165. Authors at Dept. Erdwissenschaften, ETH Zurich, CH-8092 Zurich, Switzerland.

Models for the generation of fluids, including a melt phase, by dehydration reactions during regional metamorphism have been constructed assuming that crustal permeability is solely dependent on porosity. In the lower crust, strain rates are such that significant crustal porosity can be maintained only if rock pores and fractures are filled by fluids at P close to lithostatic. Excesss fluid P are relieved by fluid microfracturing or magmafracturing. Dehydration and hydration reactions, with or without a melt phase, are the primary control of fluid fluxes and crustal porosity. In large scale models (10 to 100 km), rates of generation of metamorphic fluids are controlled predominantly by the metamorphic heat source.

Average porosities obtained by modelling are small (<0.05%), with the result that metamorphic fluids are inefficient transporters of both heat and mass. However, porosity may transiently increase to values greater than 1% so that transport by fluid advection may be important on local spatial and temporal scales within the crust. Transient increases in porosity occur when the migration of fluids results in chemical instability, e.g., when a water-rich fluid moves into a rock in equilibrium with a CO_2-rich fluid and causes exothermic reactions. Such reaction enhances porosity and permits fluid infiltration for a time period that is limited by the rate of reaction and magnitude of the fluid flux. (Authors' abstract)

THOMPSON, J.M. and FOURNIER, R.O., 1988, Chemistry and geothermometry of brine produced from the Salton Sea Scientific drill hole, Imperial Valley, California: J. Geophy. Res., v. 93, no. B11, p. 13,165-13,173. Authors at U.S. Geol. Survey, Menlo Park, CA.

The December 29-30, 1985, flow test of the State 2-14 well, also known as the Salton Sea Scientific drill hole, produced fluid from a depth of 1865-1877 m at a reservoir T of 305° ± 5°C. Another flow test at a depth of 3170 m produced brine contaminated by drilling fluid and diesel oil. Therefore we focus on the first flow test. Samples were collected at five different flashing P. The brines are Na-Ca-K-Cl-type waters with very high metal and low SO_4 and HCO_3 contents. Compositions of the flashed brines were normalized relative to the 25°C densities of the solutions, and an ionic charge balance was achieved by adjusting the Na concentration. The composition of the preflashed reservoir fluid was calculated using enthalpy-chloride relations applied to the normalized and charge-balanced brines. The calculated total dissolved solids in the preflashed reservoir fluid ranges from about 24.8 wt %, assuming insignificant thermal losses from the erupting fluid before sampling, to 26.0 wt %, assuming a 10% enthalpy loss by conduction of thermal energy through casing and surface piping. The preferred total dissolved solids of the reservoir fluid is 25.05 wt %. The calculated specific density of the preflashed reservoir fluid at 305°C and 1870 m depth ranges from 0.9980 (no thermal loss prior to sampling) to 1.0107 ± 0.0023 g cm^{-3} (10% thermal loss). Of the various cation geothermometers that are now in common use, the Na-K-Ca method gives a T (310°C) closest to the measured T (305°C) in the production horizon. Calculated Na/K geothermometer T, using equations suggested by different investigators, range from 326° to 364°C. The Mg/K^2 method gives a T of about 350°C, Mg/Li^2 about 282°, and Na/Li 395°-418°C. (Authors' abstract)

THOMPSON, T.B., 1988, Geology and uranium-thorium mineral deposits of the Bokan Mountain granite complex, southeastern Alaska: Ore Geol. Reviews, v. 3, p. 193-210. Author at Dept. Earth Resources, Colorado State Univ., Ft. Collins, CO 80523, USA.

The Bokan Mountain (Kendrick Bay) uranium-thorium deposits are associated with a Late Jurassic peralkaline granite ring-dike complex. The uranium-thorium deposits form pipe-like bodies along contacts, or occur as pods in en echelon northwest-striking shear zones.

Filling T in ore stage fluid inclusions within quartz range from 320-331°C with P corrections increasing the T of formation to 420°C or higher, depending on dissolved gas content. Sulfur isotopic analyses on pyrite, galena, sphalerite and pyrrhotite indicate disequilibrium, but $\delta^{34}S(H_2S)$ is estimated at 7.5‰. Carbon and oxygen isotopic analyses on ore stage calcite yield $\delta^{18}O(H_2O)$ of 6.8 to 8.1%, and $\delta^{13}C(\Sigma C)$ of -4.3 to -7.0‰. The oxygen and carbon isotopic data support a magmatic origin for the calcite and associated thorium-uranium deposits. (From the author's abstract by H.E.B.)

THOMPSON, T.B. and BEATY, D.W., 1988, The origin of the Leadville district: A century of research and the development of a comprehensive genetic model (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A38-A39. First author at Dept. Earth Resources, Colorado State Univ., Ft. Collins, CO 80523.

The Leadville district stands as a classic locality for two reasons. First, the district has been long-lived and extemely valuable. Secondly, and perhaps more importantly, Leadville occupies a unique position in scientific history. It was the first ore deposit in North America to be studied in detail by U.S. Geological Survey economic geologists (by S.F. Emmons, beginning in 1879). Emmons provided much of the basic geologic database that has led to comprehensive, unambiguous genetic model. Past genetic models for the Leadville district have included ore fluids of descending (Emmons, 1886) and ascending (Emmons et al., 1927) origin, ore fluids of magmatic (Loughlin and Behre, 1935) and basinal (De Voto, 1983) origin, and mineralization processes of Laramide (Tweto, 1968) and Pennsylvanian (De Voto, 1983) age. Our recent research has added extensive new data on basic field relations; hydrothermal alteration; oxygen, sulfur, and Pb isotopes; fluid inclusions; and fission-track geochronology. These data indicate some of the proposed genetic models are partially correct but incomplete.

Pb and sulfur isotopes indicate deep crustal igneous sources for the ore components. Oxygen and hydrogen isotopes indicate that the transport mechanism involved in aqueous fluid of magmatic origin. FI indicate that the mineralization process involved T = 350°-450°C. Sphalerite geobarometry indicates a P of 1.2 Kb. Geochronologic studies date the mineralization event at about 34 Ma. The district lies on the perimeter of a large gravity low, inferred to reflect the concealed source stock. (Authors' abstract)

THORN, P.G., 1988a Fluid inclusion and stable isotope studies at the Chicote tungsten deposit, Bolivia: Econ. Geol., v. 83, p. 62-68. Author at Dept. Geol., Marischal College, Univ. Aberdeen, Aberdeen AB9 1AS, Scotland.

The W-bearing veins at Chicote are restricted to a zone of pervasive hydrothermal alteration extending over an area of 3,250 by 1,000 m with a vertical range of over 1,600 m. The mineral paragenesis follows an oxide-sulfide-carbonate sequence. Peripheral to the W mineralization is a zone of Sn-bearing veins. No igneous rocks are exposed in the vicinity of these mines.

Fluid inclusion studies demonstrate that the ore fluids are complex brines with salinities of 5 to 48 eq wt % NaCl and trapping Tt of 195° to 530°C. The salinities and T of the fluids display a progressive decrease with time. Stable isotope analyses for $\delta^{18}O$ and δD on vein quartz and siderite suggest that the mineralizing fluids were magmatic in origin.

Despite strong similarities in mineralogy between Chicote and other W deposits, such as Panasqueira in Portugal and Pasto Bueno and San Cristobal in Peru, there are important differences. The ore fluids were far more saline than the typical worldwide trend and were dominantly magmatic. The hypersaline Chicote ore fluids provided a suitable medium for the transport of W and precipitation was probably caused by a decrease in T and P (From the author's abstract)

THORN, Peter, 1988b, A tungsten vein deposit in Bolivia: Geology Today, v. 4, p. 176-178.

See previous item. (E.R.)

TILLEY, B.J., 1988, Diagenesis and porewater evolution in Cretaceous sedimentary rocks of the Alberta Deep Basin: PhD dissertation, Dept. Geol., Univ. Alberta, Edmonton, Alberta.

The Alberta Deep Basin is the westernmost part of the Western Canadian Basin where the sedimentary section thickens towards the Cordillera. Almost the entire Mesozoic section is gas-saturated and consists of Cretaceous conglomerates, sandstones, and shales, and Triassic and Permian carbonates, evaporites, and clastic rocks. Three major stages of diagenesis and porewater evolution in Cretaceous clastic rocks of the Deep Basin correspond to three different flow regimes which were controlled by geological events and maturation of organic matter. During burial in a flow regime driven by compaction and diagenetic reactions, early diagenetic hematite, siderite and chlorite were followed by later stages of chlorite, kaolinite, quartz, and illite precipitation, dissolution of K-feldspar and carbonate cements, and albitization of feldspars. In most Cretaceous units, early porewaters $\delta^{18}O$ values = -12 to -7‰ SMOW) evolved to waters with $\delta^{18}O$ values $\leq$ +3‰. Infiltration of saline fluids from pre-Cretaceous rocks may have produced more saline and ^{18}O-rich porewaters in the Cadomin Formation.

During late stages of the Eocene Laramide Orogeny, burial depths in the Western Canadian Basin and hydraulic potentials were at their maximum. Gravity-driven meteoric water penetrated to depths were T were >190°C, then moved updip to the east along permeable pathways. Emplacement of these hot fluids into cooler updip rocks created a local thermal anomaly. Fluid inclusion and stable isotope analyses of quartz druse precipitated by the hot fluids, and of diagenetic dickite, ankerite and calcite precipitated during uplift, indicate the involvement of a significant fraction of meteoric water during the formation of these phases.

Subsequently, saturation of the western part of the Deep Basin by gas resulted in the interruption of both diagenesis and recharge by meteoric water originating in the west. Solutes in porewaters to the east of the gas-saturated zone were redistributed between the fluids in the various rock units. Gravity-driven meteoric fluids were redirected around the gas-saturated barrier and entered the eastern part of the Deep Basin where they mixed with older saline porewaters. (Author's abstract)

TINGLE, T.N., GREEN, H.W., and FINNERTY, A.A., 1988, Constraints from carbon-14 beta track autoradiography on the solubility and diffusivity of carbon in olivine at mantle pressures (abst.): EOS, v.69, p.521-522.

TORGERSEN, T., 1988, ^{4}He and ^{40}Ar evidence for the large-scale nature of fluid transport in the crustal degassing process (abst.): EOS, v.69, p.467.

TOURAY, J.C., 1988, Fluid inclusions in Mississippi-Valley type (M.V.T.) ore deposit studies; a review: Colloque Int'l.: Mobilité et concentration des métaux de base dans les couvertures sédimentaires: manifestations, mécanismes, prospection, Orléans, [1988] (in French; English abstract).

Fluid inclusions (F.I.) in transparent minerals (fluorite, barite, sphalerite, quartz, carbonates) from the M.V.T. and related or deposits can be characterized by microthermometry. On the basis of T salinity, Ca/Na ratios and usual presence of trapped hydrocarbons, fluid inclusion have directly been compared to oil-field brines.

An improved understanding of F.I. results from technological improvements. In this respect, new insights have been derived from better chemical analysis of trapped solutions (using Scanning Electron Microscopy and Energy Dispersive Analysis of individual inclusion decrepitates) trapped gases (using Raman Microprobe) and trapped liquid hydrocarbons (using Infrared Microprobe).

F.I. studies lead to the concept of ore precipitation from 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. On the other hand, F.I. microthermometry offers the best T estimate for the time of ore deposition provided a F.I. time scale has been correlated to the paragenetic sequence. Low P geobarometry is now possible from preliminary isochores for trapped "oil" (about 3°C bar^{-1} in the 100-250°C and 1-500 bar range). Geodynamical interpretations of F.I. data in M.V.T. ore deposits require, within the same sedimentary basin, comparisons with F.I. data from transparent diagenetic minerals. This approach is illustrated by case studies within the Northern Tunisian Mesozoic basin and on the western passive continental margin of the Tethysian basin. (Author's abstract)

TOURAY, J.C., BENY, C. and BOUHLEL, S., 1988, Electron microprobe and micro-Raman characterization of barite-celestite solid solutions: C.R. Acad. Sci. Paris, v. 306, Sèrie II, p. 1353-1357 (in French; English abstract).

Barite-celestite solid solutions have been analyzed by electron microprobe, with from 2 to 15 reliable analyses per sample; they were revealed to be homogeneous or heterogeneous (with respect to Sr content) at the scale of 1 mm^2. Raman scattering spectra were recorded, using a UMIL Jobin-Yvon Raman microprobe, in the 1250 to 100 cm^{-1} range. In chemically homogeneous areas, the frequency of peak stretching of the S-O bond varies linearly with respect to composition between 987.5 cm^{-1} (barite) and 1000 cm^{-1} (celestite). This property may be used for analyzing deep-seated microinclusions of barite-celestite in transparent minerals. (Authors' abstract)

TOURAY, J.-C. and GUILHAUMOU, N., 1987, Thermal evolution of the southern subalpine domain (Drome, Alps of Haute-Provence): Contribution from fluid inclusion studies (abst.), in "Le detritisme dans le sud-est de la France" ("Detrital rocks in south-eastern France"), edited by the "Assoc. des Gépl. francais de l'est," book of abstracts of the meeting, Chambery, France, December 10-12, 1987, p. 19 (in French). First author at Ecole Supérieure de l'Energie et des Matériaux, Univ. d'Orléans, B.P. 6759, 45067 Orléans Cédex 02 et UA CNRS no. 724, France.

Since the first description of methane-dominated fluid inclusions in neoformed quartz in the septaria of Rémuzat (Touray and Jauzein, 1976), research has been undertaken concurrently with the studies carried out in the helvetic domain (Mullis, 1979). Microthermometric studies, bulk gas analysis, studies on clay minerals, and the reflectance of disseminated organic matter have revealed the presence of a western domain that has evolved up to conditions of diagenesis (oil window), and of an eastern domain that has reached the anchizone (dry gas). The boundary is well defined, and is close to the thrust-fault of Digne. It underscores the extent of the vertical movement of this break bringing closer the two domains that have evolved under different thermal conditions (Th of aqueous inclusions: 150° to 160° in the west, and 180° to 220° in the east. Barlier, 1974; Touray and Barlier, 1975; Touray, 1984). Additionally, recent data has been obtained by fluorescence microscopy, and Raman microspectrometry (Beny and Guilhaumou, 1985; Velde and Guilhaumou, in press). One can distinguish: non-fluorescent gaseous inclusions (eastern domain), blue or white fluorescent liquid-dominated or gaseous-dominated inclusions (western domain), and late-stage yellow fluorescent inclusions, essentially in the western domain. Raman-analysis reveals the presence of mixtures of "wet gas" types (CH_4, C_2H_5, C_3H_8, and accessory N_2, H_2S, and CO_2) in the west, and "dry gas" types in the east (CH_4 and CO_2).

Following results have been obtained during fluid inclusion studies of neoformed minerals in diapirs of the vocontian domain (Perthuisot and Guilhaumou, 1983): quartz, albite, and dolomite contain hypersaline P inclusions (with halite and sylvite dms), and gaseous-dominated P inclusions (CO_2 and N_2 in variable proportions). Their coexistence is evidence for a "forced immiscibility." T-P interpretation leads to following estimates: 250°C and 1.5 kb at Propiac and Montaulieu, 360°C and 2.2 kb at Suzette.

Similar "Triassic-looking" bipyramidal quartz crystals (solid inclusions of anhydrite, carbonate, feldspars, talc ... hypersaline inclusions, gaseous inclusions with CO_2, and N_2) have been found in some places in the Terres Noires, where they appear to have been reworked (Desmaisons et al., in press). Such an observation suggests the existence of hydrothermal circulations, major local thermal gradients, and halokinetic motions in the early Jurassic.

In conclusion, for the geographical area under study, fluid inclusions yield information on the thermal evolution at the scale of a basin, as well as on locally superimposed anomalies. (Authors' abstract, translated by R. Moritz)

TOURET, J.L.R., 1987, Fluid inclusions and pressure-temperature estimates in deep-seated rocks, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 91-121. Author at Inst. Earth Sci., Free Univ., P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.

Recent major developments (Raman analysis, theoretical knowledge of multicomponent systems ...) have brought the theory and technique of fluid inclusion studies to a state approaching maturity. The number of well studied cases remains, however, limited, and many researchers hesitate to engage in a type of study that they consider highly specialized, time consuming and with questionable results. The different steps of fluid inclusion studies of metamorphic rocks are critically examined; three aspects are especially important:

- Fluid inclusion data must be compared with other dependent estimates, in order to place fluid inclusions in their petrographic context.
- The representativity of measured fluid inclusions is always a major problem, which requires an extremely precise and complete <u>observation</u> of the investigated sample.
- The major theoretical limitation lies presently in the determination of the <u>molar volume</u> of the fluid. Binary systems (CO_2-H_2O, CO_2-N_2, CO_2-CH_4) can now be studied, combining phase transition T (microthermometry), chemical composition (Raman analysis) and theoretical equations of state. Much experimental work remains however necessary on a large PT field of geological interest. (Author's abstract)

TOURET, J.L.R., 1988a Synmetamorphic fluid inclusions in granulites (abst.): Terra cognita, v. 8, p. 255-256. Author at Earth Sci. Inst., Free Univ., Amsterdam, The Netherlands.

Many granulites contain high-density, CO_2-rich fluid inclusions, which have played a decisive role in the elaboration of the concept of "carbonic metamorphism." This requires that the CO_2-rich fluids are synmetamorphic, an idea which is now challenged by several workers. The basic criteria for the identification of synmetamorphic inclusions are reviewed and clarified.

Neither high-density nor coincidence between CO_2 isochores and mineral P-T estimates are sufficient. In the general case where several fluid generations are present, fluid chronology must be established precisely. Synmetamorphic fluids are then identified from several sets of arguments: i) earliest, primary inclusion densities consistent with PT metamorphic conditions, ii) later fluids falling on different isochores, iii) fluid composition compatible with the mineral assemblage.

This has been realized in several, well documented examples (India, Baltic Shield, etc.) and several conclusions can be derived - Synmetamorphic CO_2 exists, sometimes in great quantities, but very locally. It seems to be most abundant near synmetamorphic, mantle-derived intrusives. Large-scale CO_2 transfer is directly connected to magmatic activity.

- Besides CO_2, NaCl-rich brines might also be present, coexisting immiscibly with CO_2. Some of these represent remnants of premetamorphic fluids which were able to persist through the whole metamorphic cycle.
- Post-metamorphic P-T paths, convex toward T ("adiabatic uplift") are not the rule, at least during the earliest stage of post-metamorphic evolution. "Isobaric cooling" paths are more common, especially within the low to intermediate P types of granulites. (Author's abstract)

TOURET, J.L.R., 1988b Nature and interpretation of fluid inclusions in granulites: Workshop on the Deep Continental Crust of South India, Jan. 9-23, 1988 (Geol. Soc. India and Lunar & Planet. Institute).

A discussion of the problems inherent in the interpretation of fluid inclusions from granulites. Good samples, very careful observations, and comparison with other independent evidence are required. See Touret, 1987a and b, in Fluid Inclusion Research, v. 20, 1987, p. 383-384. (E.R.)

TOURET, J.L.R. and HANSTEEN, T.H., 1988, Geothermobarometry and fluid inclusions in a rock from the Doddabeta charnockite complex, southwest India:

Rendiconti della Soc. Italiana di Min. & Petrol., v. 43, p. 65-82. First author at Inst. Earth Sci., Free Univ., de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

A deformed, garnet and orthopyroxene-bearing charnockite from Dodda Betta near Ooty, Nilgiri Hills, India, contains many CO_2 fluid inclusions in 3 major minerals (garnet, plagioclase and quartz). Detailed study of the mineral phases places PT peak metamorphic conditions at 8 ± 0.7 kb and 800± 15°C, respectively. The rock is conspicuously deformed and recrystallized (quartz more than plagioclase), whereas garnet has resisted the deformation. The densities of the CO_2 inclusions in each mineral are relatively uniform, and they increase in order of increasing deformation from 0.96-1.02 g/cm^3 in garnet to 1.12 g/cm^3 in quartz. P inclusions in garnet correspond to a P about 1 kbar lower that peak metamorphic conditions. Higher densities in plagioclase and quartz indicate a post metamorphic P-T-trajectory concave towards T axis ("isobaric cooling"). Geodynamic implications and fluid regime after metamorphism (important quantity of free CO_2 during mineral growth) are discussed. (Authors' abstract)

TRACY, R.J. and SHEETS, R.W., 1988, H_2S-rich fluids in high-grade sulfidic schists: Evidence from fluid inclusions and from fluid calculations based on metamorphic equilibria (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 79. Authors at Dept. Geol. Sci., VPI & State Univ., Blacksburg, VA 24061.

Highly sulfidic and graphitic pelitic schists from central Massachusetts contain the metamorphic assemblage quartz-Kfeldspar-plagioclase-biotite-cordierite-sillimanite-rutile-graphite-pyrrhotite ± pyrite, which has been estimated to have formed at about 700°C and 6 kbar using thermobarometric techniques on nearby garnetiferous samples. At these high P and T conditions, the two-sulfide association (found in several smaples with iron-free biotite and cordierite) buffers a high S_2 fugacity ($\log fS_2 = +0.4$). At the low fO_2 values appropriate to graphite stability, this results in calculated fluid compositions (assuming ideal mixing) in which the major constituents are H_2S, H_2O and CO_2. For example, at $\log fO_2 = -18.0$ (or best estimate for these samples), the X_i values are: H_2S - 0.581, H_2O - 0.322, CO_2 - 0.083, CH_4 - 0.012, H_2 - 0.002. Pyrrhotite-only samples which equilibrated under different S_2 and O_2 constraints ($\log fS_2 \approx -3.0$; $\log fO_2 \approx -18.5$) yield a quite different calculated fluid: H_2S - 0.036; H_2O - 0.794, CO_2 - 0.051, CH_4 - 0.113, H_2 - 0.006. Petrologic evidence for this difference in fluid compositions exists: Mg-cordierite in two-sulfide rocks contains over 1 wt.% H_2S (presumably replacing water in the structure) whereas cordierite in other ampless has no detectable H_2S.

Three types of fluid inclusions have been found in quartz and Kfeldspar in the samples examined. All samples contain Type 1 (methane-rich) and Type 2 (water-rich) inclusions. Only the two-sulfide sample, however, yielded Type 3 fluid inclusions in quartz (adjacent to both pyrite and pyrrhotite) in which Th above 31°C suggest the presence of H_2S. Sparse data on H_2S-bearing fluids (in the CH_4-H_2S system) suggest that our Th data may indicate between 45 and 65 mole % H_2S in these inclusions, remarkably consistent with the calculations of fluid compositions, and considerably more H_2S-rich than any previously described metamorphic fluids. (Authors' abstract)

TROMMSDORFF, Volkmar and SKIPPEN, George, 1987, Metasomatism involving fluids in CO_2-H_2O-NaCl, in H.C. Helgeson (ed.), Chemical Transport in Metasomatic Processes, 1987, D. Reidel Pub. Co., p. 133-152. First author at Inst. Mineral. & Petrogr., ETH-ZENTRUM, CH-8092 Zürich, Switzerland.

Phase relations in the system, CO_2-H_2O-NaCl, are used to model metamorphic fluids in carbonate rocks. It is possible that two fluid phases coexist along most T-depth paths in metamorphic rocks if the chloride content of the fluid system is adequate. The presence of two fluid phases is shown to have considerable influence on the evolution of fluid composition in reacting metasomatic systems. An aqueous brine interacting with dehydration, decarbonation, hydration-decarbonation and dehydration-decarbonation equilibria is considered. Dilution of a one-phase fluid describes the process involving dehydration equilibria. Dilution of the brine by CO_2 as in the remaining three reaction types drives fluids into a two-phase region of coexisting liquid and vapor. Saturation in NaCl is shown to be possible for systems undergoing hydration-decarbonation reactions. Irreversible reaction is possible in systems undergoing dehydration-decarbonation. The rate of reaction progress increases in systems that reach saturation with respect to halite. Still greater rates of reaction progress are possible in systems undergoing irreversible reaction. (Authors' abstract)

TRUDU, A.G. and BLOOM, M.S., 1988, A genetic model for the origin of hypogene gold in porphyry copper systems: The Tirad porphyry copper-gold deposit (Guinaoang, NW Luzon, Philippines) (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 211-216. Authors at Dept. Earth Sci., Monash Univ., Clayton, Vic. 3168, Australia.

Fluid inclusions occur in quartz and plagioclase phenocrysts (together with silicate melt inclusions) of the Tirad stock and in vein quartz and anhydrite. The complexity of superimposed arrays of different inclusion types renders unambiguous assignment of origin difficult. Seven fluid inclusion types are recognized: two vapor-rich, two liquid-rich, two hypersaline (C-1 with halite ± hematite dxls and C-2 with ≤ 5 dms in addition to halite ± hematite) and one vapor-rich and halite-saturated.

Cogenetic fluid inclusion assemblages have been established which reflect the type, abundance and distribution of inclusions in relation to the diagnostic silicate, sulfide and/or oxide phases of the attendant alteration, and to the occurrence of Au. Coexisting hypersaline (type C-2) and vapor-rich inclusions are correlated with K-silicate alteration/mineralization in which Au deposition occurs in veins and is coeval with quartz, magnetite and bornite. Te for these hypersaline inclusions is -30 to -70°C. Th, uncorrected for P, vary between 300°C and 600°C and average 413°C. Such variation in Th can be interpreted either as trapping of vapor-liquid mixtures from a single, two-phase fluid, in which case the minimum Th are most representative of prevailing T, or as recording diverse solutions.

K-silicate alteration is overprinted by hypersaline type C-1 coexisting with a vapor-rich phase, thus indicating the presence of two immiscible fluids. The brines have Th averaging 376°C and salinities <45 wt% NaCl, high-lighted by the absence of a complex daughter crystal assemblage contained in the inclusions. Free Au inclusions in quartz containing population 2 inclusions have been observed. Replacement of magnetite by hematite is a common texture, as well as the association hematite-chalcopyrite-Au. The fluid, presumably evolved compositionally from an inclusion fluid typical of K-silicate alteration, was favorable to both Au and copper deposition.

White sericite alteration (+Au) is still later; L-rich and V-rich inclusions, suggesting boiling, have Th average <300°C and <15 eq. wt% NaCl. (From the authors' abstract)

TRUFANOV, V.N., KURSHEV, S.A., MAISKII, Yu.G. and USHAK, A.T., 1987, Scientific basis for informativeness of natural mineral-fluid systems on mineral genesis: Izv. Sev.-Kavk. Nauchn. Tsentra Vyssh. Shk., Estestv. Nauki 1987, no. 3, p. 107-115 (in Russian). Authors at Rostov. Gos. Univ., Rostov, USSR.

In localization of endogenic ore deposits, the reaction between mineral and the fluid (FI) phase occurs in one of two fundamental systems: (1) closed systems, in which the FI phase is trapped in the crystal matrix of minerals and (2) open systems, in which the FI phase serves as the external medium for the crystallizing minerals. The basis under which data on natural mineral-FI systems of close type, i.e., on small FI inclusions trapped in minerals, can be used to interpret the formation conditions of a mineral deposit are considered. The composition, d., size, amount, and mode of occurrence of these inclusions reflect the various stages of mineral formation. The closed system is marked by phase-different FI inclusions, inclusions of clathrate compounds, and intrinsic FI radicals. A diagram relating the T of (1) decrepitation, (2) conservation, and (3) homogenization of FI inclusions in quartz to the T and P of mineral formation is presented. (C.A. 109: 25381g).

TRUMBULL, R. and MORTEANI, G., 1987, Tin mineralization in Archean pegmatites in Swaziland and a potential exploration method based on trace elements in pegmatitic feldspar, in Current research in African earth sciences, G. Matheis and H. Schandelmeier, eds., 1987 Balkema, Rotterdam, p. 405-408. Authors at Lehrstuhl für Angewandte Mineral. & Geochem., Tech. Univ. München, Garching, FRG.

Th for P fluid inclusions in cassiterite = 230-300°C, however they are too small to obtain freezing data. These T give a minimum estimate of crystallization T and have not been corrected for P. The inclusions (S) in adjacent quartz show the same Th and a salinity of 15-20% NaCl eq., which may be appropriate to the mineralizing solutions. These data are consistent with the geochemical model of Eugster, 1986, where Sn is transported at high T as a chloride complex. (E.R.)

TSAMERYAN, O.P., ZAKARIADZE, G.S., SOBOLEV, A.V. and KONONKOVA, N.N., 1988, Classification of ophiolitic volcanic rocks of the Lesser Caucasus based on the composition of rocks and melts: Geokhimiya, 1988, no. 8, p. 1140-1158 (in Russian). Authors at Inst. Geokhim. Anal. Khim., Moscow, USSR.

Temperatures of crystallization and the composition of melts involved in formation of effusive rocks in the ophiolite complex of Lesser Caucasus were determined by thermobarogeochemical technique. Based on the data obtained, along with petrochemical data on these rocks, a classification of Lesser Caucasus ophiolite volcanic series was devised. Alkaline and subalkaline series of the intraplate magmatism, series of tholeiites of oceanic rifts and their water-enriched analogs, typical of the marginal seas, as well as island-arc series (represented by boninites and island-arc tholeiites) are distinguished. The exclusively broad range of compositional variations and volcanism types in the Upper Jurassic-Cretaceous ophiolite complex of the Lesser Caucasus has no direct analogs among the ophiolites of the Mediterranean and other regions. (C.A. 109: 153355p)

TU, Dengfeng, 1988, A study of inclusions in fluorite from the Shuangjiangkou-Jiangjunmiao fluorite ore deposit in Hunan Province: Chinese J. Geochem., v. 7, no. 3, p. 281-287.

TUGARINOV, A.I. and VERNADSKY, V.I., 1980, Dependence of the decrepitation temperature of minerals on their gas-liquid inclusions and hardness: Dokl. Akad. Nauk SSSR, v. 195, p. 112-114.

Missed in earlier volumes. (E.R.)

TURNER, D.R. and BOWMAN, J.R., 1988, Modeling of temperature-fluid flow regimes in the Empire Zn-skarns, Hanover, NM (abst.): Geol. Soc. Am. Abstract Programs, v. 20, p. A93.

TURNER, Grenville, 1988, Hydrothermal fluids and argon isotopes in quartz veins and cherts: Geochimica Cosmo. Acta, v. 52, p. 1443-1448. Author at Physics Dept., Sheffield Univ., Sheffield, England.

Argon isotopes from a number of sources are present in quartz veins and chert; in situ decay of K, parentless ^{40}Ar leached or outgassed from surrounding rocks, atmospheric Ar dissolved in ancient hydrothermal fluids, and, modern atmospheric Ar. The manner in which the ^{40}Ar-^{39}Ar techniques can be used to unscramble these components, by way of correlations with Cl and K, is described in relation to two parallel studies of vein quartz and the Gunflint chert. Information concerning several processes can be inferred, including: contributions of surface waters to trapped fluids (from the concentration of atmospheric Ar in the fluids), degree of water-rock interaction (from the concentration of parentless ^{40}Ar and/or the ratio of parentless to atmospheric Ar), effects of dilution of P hydrothermal brines by meteoric water (which results in a decrease in the ratio of both Cl and parentless ^{40}Ar to atmospheric Ar), effects of boiling (from low concentrations of atmospheric Ar and an increase in Cl/^{40}Ar). The K-Ar chronology of deposition can also be inferred in suitable circumstances. In principle the (^{40}Ar/^{36}Ar) ratio of the ancient atmosphere can be determined from fluids free of parentless ^{40}Ar. However, a (^{40}Ar/^{36}Ar) ratio determined for a low salinity end member in Gunflint chert probably reflects the presence of modern meteoric water. (Author's abstract)

TURNER, G. and BANNON, M.P., 1988, ^{40}Ar-^{39}Ar analysis of fluid inclusions in quartz and fluorite associated with mineralization (abst.): Chem. Geol., v. 70, p. 132. Authors at Dept. Physics, Univ. Sheffield, S3 7RH, UK.

Argon in fluid inclusions within quartz and fluorite from mineralization associated with the Cornubian Batholith and the North Pennine Orefield has been analyzed following neutron irradiation, in-vacuo crushing, and stepped heating. Crushing releases a Cl-correlated component which contains excess argon and ancient atmospheric argon dissolved within the fluids. Stepped heating releases a K-correlated radiogenic component associated with the solid phases. A knowledge of the salinity of the inclusions obtained by thermometric analysis allows the absolute concentration of the argon components in the fluids to be calculated. Concentrations of the excess component can be used as a semi-quantitative measure of fluid-rock interaction. An extensive study of the Cornubian samples indicates a significant systematic variation in the ratio of the excess component to atmospheric argon between early fluids involved in the Sn-W mineralization and the later fluids responsible for polymetallic sulphide mineralization. The early fluids contain a high concentration of excess argon; the later fluids have been diluted by meteoric water and have lower excess ^{40}Ar and Cl concentrations. The absolute concentration of atmospheric argon is similar in all the fluids and is that expected for water which has equilibrated with the atmosphere. A preliminary study of fluorite from the North Pennines has shown a systematic increase in the ^{37}Ar/^{40}Ar ratio during crushing experiments which release gas from progressively smaller inclusions. This can be understood in terms of recoil of ^{37}Ar into the inclusions during irradiation of the sample, and provides a method of estimation of the size distribution of the inclusions involved. (Authors' abstract)

TURNER, G., BURGESS, R. LAURENZI, M., KELLEY, S. and HARRIS, J., 1988, ^{40}Ar-^{39}Ar laser probe dating of individual inclusions in diamonds (abst.): Chem. Geol., v. 70, p. 142. Authors at Physics Dept., Univ. Sheffield, UK.

A laser probe is being used to measure ^{40}Ar-^{39}Ar ages from individual mineral inclusions in diamonds of eclogitic paragenesis from the Premier mine. Initial results obtained from a single garnet inclusion, which is presumed to have remained closed to argon diffusion since it became enclosed by the diamond, indicated an age of 1440 ± 140 Ma, slightly older than the emplacement age of the host kimberlite. This observation is similar to that based on Sm-Nd measurements made on aggregates of inclusions exctracted from diamonds of eclogitic paragenesis from Premier. It contrasts with much older Sm-Nd model ages obtained on diamonds of periodotitic paragenesis from Finsch and Kimberly.

The small amounts of radiogenic argon involved are two orders of magnitude lower than in any previously reported age determination. Because of the inability to apply a conventional atmospheric argon correction based on ^{36}Ar, accuracy is determined by the reproducibility of blanks. The chemistry of the inclusion, which based on visual observation was an orange garnet, was determined from ^{37}Ar, ^{39}Ar and ^{38}Ar produced in the neutron irradiation as: [Ca] 9%; [K] 60 ppm; [Cl] 10 ppm. The presence of potassium in the garnet was somewhat surprising. Even more surprising were the strong variations in (K/Ca) and (Cl/Ca) based on (^{39}Ar/^{37}Ar) and (^{38}Ar/^{37}Ar) from different parts of the inclusion. Since the inclusion is presumed to be an equilibrium assemblage, this observation may indicate the presence of an additional mineral such as pyroxene. Laser probe ^{40}Ar-^{39}Ar ages for a further ten clinopyroxene inclusions from Premier diamonds will be presented. (Authors' abstract)

TURNER, G., WANG, S., BURGESS, R. and BANNON, M., 1988, Argon and other noble gases in fluid inclusions (abst.): Chem. Geol., v. 70, p. 42. Authors at Dept. Physics, Univ. Sheffield, S3 7RH, UK.

The ^{40}Ar-^{39}Ar technique coupled with thermometric analysis is being applied to the study of elemental correlations between argon, the other noble gases, and K, Cl and Ca, in fluid inclusions in a variety of mineral samples. ^{36}Ar is a tracer for dissolved atmospheric gases in the inclusions and in the samples so far analyzed has been shown to be present in absolute concentrations typical of surface waters, i.e., approximately 1 μl/l. ^{36}Ar can therefore also be regarded as a quantitative tracer for water circulation even in situations where the water cannot be observed directly. Parentless (excess) ^{40}Ar is commonly present in most inclusions, having been released by thermal diffusion, or chemically leached, into the circulating fluids. In the former situation the absolute concentration of excess ^{40}Ar provides a measure of the flux of radiogenic argon being released, in the latter it provides a measure of the degree of fluid rock interaction. In both cases the ratio of excess argon to dissolved atmospheric argon depends (inversely) on the rate of circulation of water in the region of the crust involved. Thus we have found that in the vigorous hydrothermal circulation associated with mineralization around a granite batholith concentrations of excess ^{40}Ar are relatively modest and the effect of dilution by excess free meteoric water very apparent. Low T environments such as those associated with the formation of some cherts appear to show much higher concentrations of excess ^{40}Ar. The presence of excess argon in fluid inclusions in cherts also appears to be greater in older samples, possibly due to a significantly higher flux of radiogenic gas through the crust in the past. Extension of the work to the other noble gases, including the mantle tracer ^{3}He is being carried out and will be reported. (Authors' abstract)

TURRIN, B.D., McKEE, E.H., THEODORE, T.G. and CONRAD, J.E., 1988, ^{40}Ar/^{39}Ar studies of fluid inclusions in vein quartz from Battle Mountain, Nevada (extended abst.): U.S. Geol. Survey Circular 1035, p. 75-76. Also in Geol. Soc. Am. Abst. with Programs, v. 20, p. 238.

K-Ar and ^{40}Ar/^{39}Ar age determinations indicate that igneous activity and associated hydrothermal mineralization at Battle Mountain, NV, occurred during the Late Cretaceous and in late Eocene to early Oligocene time. Studies were undertaken to evaluate the use of fluid inclusions for determining the age of hydrothermal events. ^{40}Ar/^{39}Ar total fusion age determinations were done on fluid inclusion-bearing quartz veins associated with Mo mineralization. Ages obtained from these experiments are highly variable and unreproducible and range from about 300 to about 60 Ma. These results led to the initial conclusions that the fluid inclusions contained excess ^{40}Ar and that Ar might migrate from fluid inclusions along microfractures. A series of ^{40}Ar/^{39}Ar incremental heating experiments were performed on a second split of the quartz samples. The results from these experiments yield Ar T-release age patterns that suggest the presence of excess ^{40}Ar. Calculated ages are inversely proportional to K content, suggesting a constant amount of excess ^{40}Ar within a relatively large population of grains. The ages generally do not correspond to any known igneous or hydrothermal event in the area (Late Cretaceous or late Eocene-early Oligocene). A third split of the quartz samples was analyzed by using a single-crystal laser fusion ^{40}Ar/^{39}Ar system. Analyzing single grains (~1 mm^3 or less) approaches analysis of the domain size of paragenetically homogeneous fluid inclusions. These analyses were used to evaluate the homogeneity of the fluid inclusion population. Results are widely variable. There is some clustering of the ages but they do not coincide with any known igneous or mineralizing event. Additional experiments to analyze the Ar from fluid inclusions that have a simple, single-stage history are underway. For this purpose, late Eocene fluid inclusion-bearing vein quartz from the northern part of Battle Mountain is used. Variation in Ar content in these samples that cannot be accounted for by radioactive decay of K since the late Eocene can only be attributed to Ar loss (younger ages) or excess Ar (older ages). (Authors' abstract)

UCHAMEISHVILI, N.E. and SHMULOVICH, K.I., 1988, Fluid phase equilibria during crystallization of the granitoids of Tyrny-Auz (Northern Caucasus), in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 67-73 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 427-428 (two papers). (E.R.)

UJIKE, Osamu, 1988, Probable mineralogic control on the mantle metasomatic fluid composition beneath the Northeast Japan arc: Geochimica Cosmo. Acta, v. 52, p. 2037-2046.

ULMER, Peter and LUTH, R.W., 1988a The graphite-COH fluid equilibrium in P, T, f_{O_2} space: An experimental determination at high pressures (abst.): EOS, v.69, p.512.

ULMER, Peter and LUTH, R.W., 1988b The graphite-COH fluid equilibrium in P-T-f(O$_2$) space: An experimental study at high pressures and temperatures: Carnegie Inst. Washington Ann. Rept. Director 1987/1988, p. 23-28.

Experimental determinations at 10, 15, and 20 kbar and 800-1500°C. (E.R.)

ULRICH, M.R. and BODNAR, R.J., 1988, Systematics of stretching of fluid inclusions II: Barite at 1 atm confining pressure: Econ. Geol., v. 83, p. 1037-1046.

Thirty-six fluid inclusions in barite were systematically overheated in 5° or 10°C increments to determine the amount of overheating beyond the initial Th required to cause the inclusions to deform nonelastically by stretching or decrepitation. Most fluid inclusions in barite stretch with small amounts of overheating, although one very small, round inclusion did not stretch when overheated by 160°. Of the inclusions studied, 42% (15 out of 36) stretched or decrepitated with less than 10° of overheating and 97% (35 out of 36) stretched with $<$ 60° of overheating. The amount of stretching varied from ~1° to >200°C, with the amount of stretching generally increasing with increasing amounts of overheating. Many inclusions stretched by an amount nearly equal to the amount of overheating and a few inclusions stretched by an amount greater than the amount of overheating. The amount of overheating required to initiate stretching decreased as inclusion size increased, although the data show considerable scatter. Prismatic and angular-shaped inclusions required smaller amounts of overheating to initiate stretching as compared to round inclusions with smooth walls, and irregularly-shaped inclusions were more resistant to stretching than either angular or prismatic inclusions. Our results do not permit a rigorous evaluation of the mechanism of stretching for inclusions in barite, but are not inconsistent with a mechanism that involves fracturing of the inclusion walls.

Our results indicate that, of the minerals barite, fluorite, sphalerite and quartz, commonly examined in fluid inclusion studies, barite is probably the least reliable. We do not, however, propose that fluid inclusions in barite should not be studied. Often barite is the only mineral available for fluid inclusion studies, and much valuable information may be obtained from the inclusions if care is taken during sample preparation and microthermometry. Sample preparation should be kept to a minimum and, if possible, cleavage fragments should be used rather than polished sections. If polished sections must be used, sawing, grinding and polishing procedures should be carefully monitored to minimize damage, and only low T cements should be used to mount the sample onto a glass slide. If the sample contains a range of inclusion shapes and sizes, select for study the smallest inclusions possible and those that are rounded and smooth-walled.

The Appendix of this paper describes a procedure for determining the CO_2 content of H_2O-CO_2 fluid inclusions based on the behavior of the vapor bubble during crushing tests. (Authors' abstract)

UNITED NATIONS DEPT. OF TECH. COOPERATION FOR DEVELOPMENT, 1987, Geology and gold mineralization of Surigao del Norte, Technical Rept. No. 4, 60 pp. (DP/UN/PHI-85-001/40).

Five weeks field work over 290 km^2 of Surigao del Norte showed that the predominantly andesitic Mabuhay Clastics and associated andesite lavas, which host much of the epithermal mineralization and are of Pliocene age, lie in angular unconformity on turbidites and Lower Miocene basaltic rocks and thin limestones.

Hydrothermal Au deposits and mineral occurrences throughout the area investigated are confined to the Mabuhay Clastics and associated andesites and rare dacites and to rocks immediately beneath the unconformity. Ore is of three main types: strata-bound ore, occurring as sulphide-rich or silicic replacement bodies in calcareous rocks within 200 to 300 m of the overlying Mabuhay Clastics (Siana mine, "fossil soil" Placer mine); vein-type ore within Mabuhay Clastics and underlying chloritized basalt or wacke (Tabon-Tabon vein, Plancoya vein), and within andesite intrusions; and bulk mineable ore occurring as string-stockworks in Mabuhay Clastics and intrusions (part of Placer, Motherlode, and Mapaso mine and numerous prospects). The mineralized Mabuhay Clastics and intrusions are strongly argillized and pyritized with only local silicic alteration and very minor advanced argillic assemblages.

The mineralization can be explained by rise of boiling neutral pH chloride fluids in the late stages of or following a major episode of andesitic volcanism. Fluids rose along fractures and locally along sub-vertical beds in the basalt, wacke and limestone 'basement;' in some cases the fluids continued to rise vertically forming veins in the Mabuhay Clastics, but more commonly split into irregular quartz-pyrite stringers locally resulting in bulk mineable ore. The strong argillization and pyritization in the Mabuhay Clastics and intrusive andesites suggest alteration by dissociation of H_2S in solution on moving outward from the veins and cooling without boiling.

Geological controls on Au in the project area also operated through Agusan del Norte, Surigao del Sur, and probably Davao del Norte and Dinagat Island. The Surigao del Norte Au deposits are thus part of a major epithermal metallogenic province in which mineralization is regionally strata-bound within and immediately beneath the Mabuhay Clastics and associated andesites and dacites.

Veins and argillized rocks have high values of several metals in addition to Au, especially As, Sb, T, Ag, Hg, Cl and Ca; high Tl and Mo values occur at some prospects. Carbonate-hosted replacement ore includes sulphidic bodies with high base metal contents in addition to high values of the metals associated with the vein-type deposits. Argillic assemblages (quartz-illite-pyrite) and the geochemical values indicate an erosion level of 200 m to perhaps 500 m beneath the palaeo-surface.

Of the areas with observed mineralization and supporting geochemical anomalies, three (Boyungan, Mapawa-Nabago, and Manpower) were investigated by detailed surveys in March-April 1987. Preliminary results indicate that these, in addition to Hill 664 East, and southern and western Masapelid Island including the Layab prospect, justify further work. Geochemical anomalies alone which warrant further investigation include Southeast Tubod, Sunkoy, and Bagacay Hill 204. There is a potential for replacement ore at depth beneath veins or stockworks in the Mabuhay Clastics, and a possibility of down-dip extension of ore in the Siana mine.

The epithermal mineralization palaeo-surface, of mid to late Pliocene age, has been broadly folded and eroded, so that at least the uppermost 200 m of the mineralized systems has been removed. (Authors' abstract)

Fluid inclusion Th determinations (total 16) were made on samples from two veins at the Layab mine; results were in the 190° and 240°C range, with 11 of the determinations in the 200° to 225°C range. Assuming that the fluids were boiling or near-boiling, the palaeo-depth implied by these T is 150 to 250 m.

Scarcity of calcite in the vein systems could imply that the gas content of the fluid was low, although quartz pseudomorphing calcite at Siana indicates appreciable CO_2 in some fluids. Limited data on the vertical extent of mineralization in the Tabon-Tabon vein indicates that ore grade there continues to a sub-surface depth of around 500 m; if the palaeo-surface lay not more than 250 m above the present surface at Motherlode, a moderate T for initial boiling of the rising fluids and at least a moderate gas content is indicated by comparison with the theoretical results of Cole and Drumond (1986). (From p. 47 of text)

VALETTE-SILVER, N.J., TERA, Fouad, PAVICH, M.J., KLEIN, Jeffrey and MIDDLETON, Roy, 1988, ^{10}Be-^{9}Be in the Salton Sea system (U.S.A.): Geother. Resources Council, Transactions, v. 12, p. 143-150.

VALLEY, J.W., 1988, Granulites: Melts and fluids in the deep crust (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 161 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 187). Author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706, USA.

See Valley, 1987, in Fluid Inclusion Research, v. 20, 1987, p. 388-389. (E.R.)

VALLEY, J.W., KOMOR, S.C. and BAKER, K., 1988, The Siljan Ring: Stable isotopes and fluid inclusions (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A25. Authors at Dept. Geol., Univ. Wisconsin, Madison, WI 53706.

The Siljan Ring in central Sweden is a Devonian age (362 my) impact crater (52 km diameter) in Precambrian granites (1.65 by), with an annulus of Paleozoic limestones and clastic sediments. Evidence for late fluid infiltration into the granites is provided by calcite crack cements healing impact-generated fractures, and by fluid inclusions in matrix and vein quartz. Values of $\delta^{18}O$ (Cc) in granite drill core from the Gravberg hole range from 7.3 to 22.3 SMOW with lower $\delta^{18}O$ at depth; consistent with precipitation from modern-day meteoric water at variable T (10°C at surface, 70-100°C at 6 km depth). Values of $\delta^{18}O$ in feldspar from granite range from 7.5 to 9.1 and thus low $\delta^{18}O$ values in calcite (near +10 from deep samples) are also consistent with 200-400°C hydrothermal fluids in exchange equilibrium with granite. Values of $\delta^{13}C$ in calcite from shallow cores (0-700 m) correlate with position in the Ring: -19.8 to -10 near the center of the ring, and -19.4 to +8 near the perimeter. This pattern reflects precipitation of calcite from groundwater that is dominated by organic decay near the center of the crater, but which has variably dissolved limestone from the annulus.

Secondary FI in quartz contain low salinity water (0-2 wt% NaCl) and water vapor; no CH_4 or H_2 has been detected. Fluid inclusion Tt range from 135 to 440°C. The Tt define two sample groups: a lower T group outside the annulus and at depths greater than 1500 m in the crater, and a higher T group inside the annulus and above 1500 m. Fluid inclusion Tt from shallow samples within the crater are thought to reflect hydrothermal circulation associated with impact heating. The impact-generated hydrothermal circulation and the groundwater circulation responsible for carbonate precipitation may represent a continuum, with the lower T carbonate precipitation representing the waning stages of the hydrothermal system. (Authors' abstract)

Van Den KERKHOF, A.M., 1988, The system CO_2-CH_4-N_2 in fluid inclusions: Theoretical modelling and geological applications: Ph.D. dissertation, Free Univ. Amsterdam, 206 pp.(Sometimes alphabetized under "K")

Rock samples from 7 metamorphic areas have been studied: the Furua Granulite Complex (Tanzania), high-grade metamorphic rocks from SW Norway, siliceous marbles from Pusula (SW Finland), granulites from Haut Allier (France), Dôme de l'Agout (France), coal basins of the Appalachians (U.S.A.) and the silver ore deposit of Harmsarvet (central Sweden). The phase behavior, transitions between solid (S), liquid (L) and vapor (V), of CO_2-CH_4-N_2 inclusions on cooling and subsequent warming, is more complicated than for the pure components: metastable and partial homogenization and sublimation are typical phase transitions. The interpretation of fluid mixtures (in respect of density and composition) is therefore much more difficult. Phase transitions in fluid inclusions are typical for systems of constant volume (isochoric systems) and they are different from "normal" phase behavior: traditional terms like boiling, melting and sublimation cannot be simply applied. New definitions are therefore introduced for the description of phase behavior in fluid inclusions. A classification system is proposed to describe phase behavior (between -180 and +35°C) of non-aqueous inclusions ["mostly valid for inclusions of the system CO_2-CH_4-N_2" (p.22)] and to typify the inclusions themselves.

Theoretical models ("phase diagrams") have been developed showing the correlation between molar volume ($\overline{V}$), composition (X) and temperature (T) for the different phase transitions. Most important are $\overline{V}$X and TX diagrams, representing isotherms (T=constant) and isochores ($\overline{V}$=constant) respectively. The latter diagram is firstly introduced here. Models are discussed for the binary systems CO_2-CH_4, CO_2-N_2 and CH_4-N_2; models for the ternary system are tentatively constructed by extrapolation.

Experiments have been carried out in order to produce [synthetic] fluid inclusions in quartz. In this way, gas compositions could be obtained of about 33, 55 and 77 mole% N_2. The experiments ultimately resulted to the establishment of a $\overline{V}$TX model, by which the forming conditions of many naturally occurring inclusions can be determined (e.g. from the Furua Granulite Complex and the high-grade marbles of Pusula). The combination of microthermometry, Raman analysis, theoretical models and experiments is therefore indispensable for the interpretation of multi-component gaseous systems. (From the author's summary)

van den KERKHOF, A.M., 1988b, Phase transitions and molar volumes of CO_2-CH_4-N_2 inclusions: Bull. Minéral., v. 111, p. 257-266. Author at Inst. voor Aardwetenschappen, Vrije Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands. (Sometimes alphabetized under "K")

The combined application of Raman microspectroscopy and the cooling stage of the study of fluid inclusions opens the possibility determining the molar volumes (v) of fluid mixtures in rocks. Isochoric XT-diagrams are introduced and it is demonstrated that the equations of state presently available (for example the Heyen equation for CO_2-N_2 mixtures) are not valid outside the range of experimental data used for their calibration. Measurements on CO_2-N_2 inclusions of extremely low molar volume (about 40 cm^3/mole) from the Furua Granulite Complex (Tanzania) are used as an example. Studies on fluid inclusions may therefore contribute, in a semi-quantitative way, to the improvement of equations of state for multi-component systems. (Author's abstract)

VANKO, D.A., 1988, Temperature, pressure, and composition of hydrothermal fluids, with their bearing on the magnitude of tectonic uplift at mid-ocean ridges, inferred from fluid inclusions in oceanic layer 3 rocks: J. Geoph. Res., v.93, n.B5, p.4595-4611. Author at Dept. of Geo., Georgia State Univ., Atlanta, GA.

Quartz-bearing veins in metagabbroic rocks dredged from the Mathematician Ridge, east Pacific, contain abundant fluid inclusions. Heating and freezing data on nearly 400 inclusions from seven samples allow determination of the T, P, and fluid compositions in the subseafloor hydrothermal system at the time of quartz growth. Coexisting dense halite-saturated inclusions and low-density, low-salinity vapor-rich inclusions (average 45 and 2 wt % NaCl, respectively) attest to an episode of phase separation in some samples. The phase separation occurred at about 600°-700°C and 60-100 MPa (600-1000 bars). The fact that samples formed at 60-100 MPa, suggests that the samples have been tectonically uplifted of the order of 3 km. The fluids could originally have been part of a deep axial hydrothermal circulation cell, or alternatively, they could have been formed in a deep convection cell underlying the off-axis edges of a magma chamber. Fluids are NaCl-$CaCl_2$ brines with molar Na:Ca of 4-8. This range of molar Na:Ca is very close to that of the inferred hydrothermal end-member from various active black smokers, to the measured ratios from basalt-seawater interaction experiments, and to the ratio calculated during numerical basalt-seawater interaction calculations. Crushing experiments indicate little or no compressible gas within the fluids. Fluid inclusions in albite suggest Tt of around 410°-500°C. Those in epidote may have been trapped at around 500°C and 110 MPa (1.1 kbar), or around 3 km beneath the Mathematician Ridge seafloor. (Author's abstract)

VANKO, D.A., BODNAR, R.J. and STERNER, S.M., 1988, Synthetic fluid inclusions: VII. Vapor-saturated halite solubility in part of the system $NaCl-CaCl_2-H_2O$, with application to fluid inclusions from oceanic hydrothermal systems: Geochimica Cosmo. Acta, v. 52, p. 2451-2456. First author at Dept. Geol., Georgia State Univ., Atlanta, GA 30303, USA.

Halite solubility along part of the vapor-saturated liquidus in the system $NaCl-CaCl_2-H_2O$ has been determined using the synthetic fluid inclusion technique. Data allow the construction of liquidus isotherms for T up to 500°C and bulk compositions containing >60 wt% total salt and as much as 25 wt% $CaCl_2$. Combined with previous data for the binary system $NaCl-H_2O$ and for the ternary system $NaCl-CaCl_2-H_2O$ in the low-salinity, low-T region, a preliminary ternary phase diagram can be constructed that remains incomplete only in the $CaCl_2$-rich region.

Results are applied to the interpretation of saline fluid inclusions from quartz veins in oceanic metagabbros, and can be applied to many other natural inclusions containing aqueous solutions with NaCl and $CaCl_2$ the dominant solutes. Microthermometric measurements at equilibrium of the melting T of ice [Tm (ice)] and of the dissolution T of halite [Tm (halite)] are sufficient to determine the bulk composition of the $NaCl-CaCl_2-H_2O$ fluid. (Authors' abstract)

Van REENEN, D.D. and HOLLISTER, L.S., 1988, Fluid inclusions in hydrated granulite facies rocks, southern marginal zone of the Limpopo Belt, South Africa: Geochim Cosmo. Acta, v.52, p.1057-1064. First author at Rand Afrikaans Univ., P.O. Box 524, Johannesburg 2000, South Africa.

The Archean granulite terrane of the southern marginal zone of the Limpopo belt, South Africa, was rapidly uplifted and thrust over a low grade granite-greenstone terrane. During cooling the granulites were rehydrated in a zone parallel to the contact with the low grade terrane. A sharply defined retrograde orthoamphibole isograd at conditions of >6 kbar, 625°C-650°C, $X_{CO_2} = 0.8$ was established. We made microthermometric analyses of over 1000 fluid inclusions in four samples, representing a traverse across the isograd, with the goal of characterizing the hydrating fluid. We found patterns of composition and density of inclusions to be similar to those reported from other granulite facies terranes: a few apparently pure CO_2 inclusions with densities appropriate for the P-T conditions, many CO_2 inclusions with lower densities, and aqueous inclusions of variable salinity and containing no detectable CO_2. The results suggest that the hydrating fluid may be represented by S CO_2-rich fluid inclusions. Because of their small size (most between 5 and 10 μm) and equant shapes, H_2O contents of the CO_2-rich inclusions of up to 0.3 mole fraction may not be detectable. A model for hydration of the granulites includes infiltration of a fluid into the partially cooled overthrust granulites with a T gradient decreasing towards the underthrust greenstone terrane. The fluid was probably generated by devolatization of the greenstones as they were heated by the overthrust granulites. The high CO_2 content of the calculated fluid and of the fluid inclusions suggests the hydrating fluid was CO_2-rich at the P-T conditions of the retrograde isograd. (Authors' abstract)

VAPNIK, Ye.A., 1988, The dynamics of development of granites of the Ladoga complex as indicated by CO_2 inclusions: Zap. Vses. Mineral. Obshch., v. 117, no. 3, p. 305-318 (in Russian; translated in Int'l. Geol. Review, v. 30, no. 5, p. 526-539). Author at Inst. Geol. & Geochron. of Precambrian [IGGD], USSR Acad. Sci., Leningrad, USSR.

Study of the densities of CO_2 inclusions in ultrametamorphogenic granitoids has made it possible to determine the P at which the different generations of migmatite leucosomes were formed. The data obtained by the barometry of CO_2 inclusions in granitoids in the granulite facies (zone II^b) are quite consistent with the solid-phase barometry. The estimated P of formation of the granitoids in the amphibolite facies (zone I) of up to 1.5 kbar exceed the average P obtained by garnet-biotite thermobarometry. It seems likely that the CO_2 inclusions in this case represent the local P_{fl}, which considerably exceeded the P_{lith} during the generation of the anatectic and diatectic melts. (From the author's Conclusions)

VEBLEN, D.R. and BISH, D.L., 1988, TEM and X-ray study of orthopyroxene megacrysts: Microstructures and crystal chemistry: Am. Mineral., v. 73, p. 677-691. First author at Dept. Earth & Planet. Sci., The Johns Hopkins Univ., Baltimore, MD 21218, USA.

Of possible pertinence since some fluid inclusions are found attached to oriented solid inclusions as discussed here. (E.R.)

VETÖ, Éva, 1988, Conditions of Pb-Zn ore formation in the Carpathian Neogene volcanic arc: Evidence from the Gyöngyösoroszi mine, northern Hungary: Proc. 7th Quad. IAGOD Symp.: Stuttgart, E. Schweitzerbart'sche Verlag, p. 245-252. Author at Hungarian Geol. Inst., Népstadion u. 14, Budapest 1442, Hungary.

See Vetö, 1986, Fluid Inclusion Research, v. 19, p. 459. (E.R.)

VIAL, D.S., FUSIKAWA, R., CASTRO, E.P.G. and VIEIRA, M.M.H., 1988, The sulfide-tourmaline-quartz-vein gold deposit Os Passagem de Mariana, Minas Gerais, Brazil (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 30-35. First author at DOCEGEO/CVRD-Rua São Paulo, 351 (30170) B.Hte./MG, Brazil.

Fluid inclusions in quartz, carbonate and tourmaline contained only pure CO_2 and/or weakly saline water. CO_2 inclusions represented more than 90% of all inclusions. CO_2 seems to have been trapped at several stages at decreasing densities; higher densities seem to be characteristic of mineralized veins. The lower densities (down to 0.65 g/cm^3) are present in all samples. Aqueous inclusions are scarce, but more frequent in barren veins. The salinity is low: 1.0-2.0 eq. wt% NaCl, although restricted areas in few samples may present inclusions with higher salinities. CO_2 inclusions of one group coeval with aqueous ones indicated T = 190/220°C and P = 1.2/1.4 kbar; another group T = 160°C and P = 650 bar. (From the authors' abstract)

VICENZI, E.P., RAPP, R., and WATSON, E.B., 1988, Crystal/melt wetting characteristics in partially-molten amphibolite (abst.): EOS, v.69, p.482.

VIDETICH, P.E., McLIMANS, R.K., WATSON, H.K.S. and NAGY, R.M., 1988, Depositional, diagenetic, thermal, and maturation histories of Cretaceous Mishrif Formation, Fateh field, Dubai: The Am. Assoc. Petrol. Geol. Bull., v. 72, no. 10, p. 1143-1159. First author at Dept. Geol. & Geol. Engrg., Univ. North Dakota, Grand Forks, ND 58202.

Rudist reef associated limestones comprising the Cretaceous Mishrif Formation are the major reservoirs in Fateh field, a giant oil field in offshore Dubai. In this study, Mishrif cores from four wells on the western flank of the field were examined to gain insights into the depositional, diagenetic, thermal, and maturation histories of the Mishrif Formation in this area.

The occurrence of P oil and water fluid inclusions in the same crystals of coarse equant and blocky calcite cements indicates that oil migration and late cementation were, in part, concurrent at the U-8 and U-8A locations. Geothermometry data and the PVT properties for oil and water inclusions are used together with calculations of Mishrif burial history and source maturation to determine an Oligocene-Miocene timing for late cementation and migration of oil. Initially, oil migration was as immiscible droplets in an aqueous brine, but as the pore fluid system became oil-rich, the cementation process was diminished or halted. Oil was entrapped as fluid inclusions over the time period of cementation such that oil inclusions show slightly different maturities as indicated by their fluorescence spectra. (From the authors' text by H.E.B.)

VIETS, J.G. and LEACH, D.L., 1988, Ore deposition in the Viburnum Trend of southeast Missouri by two geochemically distinct fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A39. Authors at USGS, MS 973, Box 25046, Dnever, CO 80225.

The Mississippi Valley-type deposits of the Viburnum Trend are clearly the product of two geochemically distinct ore fluids. Analyses of FI show the ore fluids that deposited the main-stage octahedral galena sulfides, which account for the bulk of the ore, are enriched in potassium, magnesium, and bromine relative to later cubic-stage galena ore fluids. Sphalerites of octahedral-stage mineralization are enriched in Fe, Mn, Ni, Co, and Ag, whereas the cubic-stage sphalerites are enriched in Ga. Previous work of Sverjensky (1981) and new isotopic data of this study demonstrate that octahedral stage galena contain isotopically heavy sulfur (mean $\delta^{34}S$ = 15.8) and less radiogenic Pb (mean $Pb^{206/204}$ = 29.919) relative to the later cubic-stage galena. Through time ore fluid chemistry changed and sulfides of the later cubic-stage galena have isotopically ligher sulfur (mean $\delta^{34}S$ = 5.1) and Pb is more radiogenic (mean $Pb^{206/204}$ = 21.723).

Previous studies suggest that the ore fluids were derived from the foreland Arkoma basin and migrated northward in response to the Ouachita orogeny. If the Arkoma basin is the source for the brines, we suggest that the two geochemically distinct ore fluids are the product of brine interaction with two chemically different aquifers. We suggest that the octahedral-stage ore fluids migrated through the basal Cambrian Lamotte Sandstone, whereas the cubic-stage ore fluids migrated through the overlying carbonates, because the cubic-stage sulfides are geochemically similar to sulfide ores in the other MVT districts in the Ozark region hosted by carbonates higher in the stratigraphic section. Alternatively, the early ore fluids may have been sourced from another basin. The Black Warrior foreland basin is an attractive source because it shares a parallel geological evolution with the Arkoma basin and early fluid migration to the Viburnum Trend might be focused along the Reelfoot Rift. (Authors' abstract)

VIGUIER, Francis, 1987, Mineralogical and geochemical study of the "talc-chlorite" deposits of La Porteille (Pyrenees, France), and of Rabenwald (Austrian Alps) (abst.): PhD dissertation, Univ. Paul Sabatier, 39 Allees Jules Guesde, 31400 Toulouse, France (in French; translated by R.P. Moritz).

A mineralogical and geochemical study has been undertaken on talc-chlorite concentrations of hydrothermal origin in the deposits of La Porteille near Montferrier (Pyrenees, Ariege), and Rabenwald (Austrian Alps). Talc was formed from carbonates and quartz, whereas the protolith of chlorite was an alumino-silicate rock. P-T conditions of formation of the deposits at Rabenwald and La Porteille are 8 to 9 kbars and 500 to 550°C, and 1 kbar and 300°C, respectively. Microthermometric studies of fluid inclusions in quartz, and their chemical analyses indicate the presence of Cl-bearing brines (salinities between 24 and 42) that are rich in Ca, Mg, Na, and K. It indicates that the activity of CO_2 was low, which explains that the transformation of carbonates into talc took place at relatively low T. (From the author's abstract).

VIKENT'YEV, I.V., PROKOF'YEV, V.Yu. and DOROFEEVA, V.A., 1988, Tectonic and fluid regime of the metamorphic redistribution of ore substance of the Tishinskoe deposit (Rudnyi Altai): Dokl. Akad. Nauk SSSR, v. 299, no. 1, p. 172-175 (in Russian). First author at State Univ., Moscow, USSR.

The studied pyrite-chalcopyrite-sphalerite-galena deposit occurs in the Kedrovsko-Butachikhinskaya fold zone in the NE margin of Rudnyi Altai as lenses and layers of massive ores in schistous Eifelian volcanic-sedimentary rocks. The deposit formed during two dynamometamorphic cycles. The transparent minerals of the ore parageneses bear inclusions with the following characteristics: quartz (35 determinations) Te -34.0 to -30.9°C, CO_2 triple point -57.0 to -56.6°C, Tm ice -12.2 to -8.7°C, Tm gas hydrate 7.2 to 8.9°C, Th CO_2 6.5 to 24.0°C in liquid, Th total 260 to 320°C, solution conc. 12 to 16 wt.%, CO_2 conc. in fluid 15.6 to 23.1 wt.%, fluid density 1.07 to 1.10 g/cm^3; dolomite (27 determinations) Te -35.4 to -32.0°C, CO_2 triple point -57.0 to -56.6°C, Tm ice -8.6 to -5.5°C, Tm gas hydrate 8.3 to 9.0°C, Th CO_2 24.5 to 28. 5°C in liquid and in gas, Th total 210 to 260°C, solution conc. 9 to 12 wt.%, CO_2 conc. in fluid 7.4 to 17.1 wt.%, fluid density 0.98 to 1.06 g/cm^3; sphalerite Te -33.1 to -32.3°C, Tm ice -4.8 to -4.6°C, Th total 155 to 190°C, solution conc. 7 to 8 wt.%, fluid density 0.95 to 0.98 g/cm^3. Metamorphic redistribution of ore substance was caused by concentrated chloride solutions bearing appreciable amounts of CO_2. (Abstract by A.K.)

VIKRE, P.G., 1988, Ledge formation at the Sandstorm-Kendall Au mine, Goldfield, Nevada (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A352-A353. Author at ASARCO, Inc., 510 E. Plumb Ln., Reno, NV 89502.

Au ore at the Sandstorm-Kendall Mine occurs in silicified fault zones or ledges that formed by both open-space filling and replacement of Miocene rhyolites 2 miles north of Goldfield, Esmeralda Co., NV. En echelon ledge segments consist of 6 assemblages, which from oldest to youngest are: (1) ledge replacement silica, (2) barite + sulfides, (3) quartz + pyrite + barite, (4) silica + barite + kaolinite breccia, (5) vuggy quartz, and (6) lateral replacement silica. Au occurs as inclusions in copper sulfosalts (mainly luzonite) and barite of assemblage (2), and in silica and barite of assemblage (4). Rhyolites enclosing the 6 assemblages are altered to quartz + kaolinite or alunite adjacent to ledges, and to illite and montmorillonite-dominated zones with distance from ledges. Quartz and kaolinite are the stable silicate phases within the ledges. T, salinities, gas concentrations and isotopic compositions for fluids in quartz and barite of all 6 assemblages display systematic variations with age. Th of primary fluid inclusions range from 292 to 230°C in assemblages (2), (3), (4) and (5), with assemblage (2) barite T exceeding those for the younger assemblages. Sulfide-sulfate isotopic T are within this range while several wall rock T vary from 241 to 200°C. Fluid salinities in assemblages (2), (3), (4) and (5) generally increase with age and range from 7.9 to 0.2 wt. % NaCl eq., with most salinities measured at about 5 wt. %. Total gas abundances in assemblages (1), (2), (5) and (6) vary from about 4 wt.% in assemblage (1) to 29 wt.% in assemblage (6). CO_2, N_2, SO_2, and H_2S are the major species. Hydrogen and oxygen isotopic compositions of water extracted from quartz and barite in the 6 assemblages are extremely diverse with $\delta D(H_2O)$ and $\delta^{18}O(H_2O)$ ranging from +18 to -137‰, and from +4.2 to -17.6‰, respectively. Spheriodal weathering of andesite preserved by assemblage (6) silica indicates that ledge segments in the Sandstorm-Kendall area are within tens of feet below the paleosurface. Subvolcanic intrusions of rhyodacite probably supplied thermal energy for mineralization both at Sandstorm-Kendall and in the main Goldfield district. (Author's abstract)

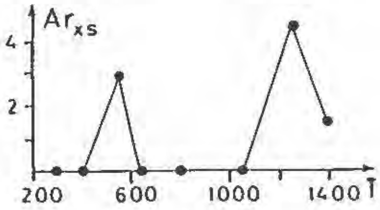
VILLA, I.M., FREZZOTTI, M.L. and GHEZZO, C., 1988, Microanalysis of quartz containing fluid inclusions: Excess ^{40}Ar in the Pulchiana (Sardinia) leucogranite (abst.): Soc. Ital. Mineral. Petrol. Mtg., Pavia, June 1988, p. 85. First author at Ist. di Geocronol. CNR, Pisa.

The Pulchiana leucogranite in Gallura (N. Sardinia) belongs to the late, post-kinematic stage of the Hercynian magmatic cycle. Rb/Sr ages for the Gallura leucogranites are tightly clustered around 289 Ma (Del Moro et al., N. Jb. Min. Abh. 126 (1975) 28, recalculated with new decay constants). The Pulchiana leucogranite contains pegmatitic pods, which sometimes have vugs later partly filled in a geode-like manner by quartz crystals.

While the pegmatite proper contains virtually no visible fluid inclusions (> 3 μm) the quartz is [crowded] with them. Microthermometric investigations give evidence of a single fluid episode. Tm values between -4° and 0°C correspond to salinities between 6 and 0% NaCl; Th (L + V → L) values range between 140° and 260°C, increasing from the rims towards the cores of the cm-sized, euhedral quartz crystals; evidently the fluid episode lasted a finite amount of time, extending over rather different T conditions. From P-T isochore considerations we estimate Tf of the quartz to be ~250-300°C, when low-salinity fluids invaded the pluton (last fluid episode in the leucogranite) in the final hydrothermal stages. The purpose of this work was to better characterize this fluid using Ar isotopes, while at the same time attempting a new experimental set-up and new data reduction procedures.

The MMMMMII (Moon & Meteorite Microextraction Manifold Mark II) described by Villa et al., (EPSL 63 (1983) 1) has the attractive feature of a low blank. Steps consisted of 10 minutes at the desired filament T, with two SAES getters at oxygen resp. hydrogen gettering T. The filament was turned off and the gas gettered 5 more minutes and directly inlet into the Varian MAT 240 spectrometer. At 600 and 1600°C this procedure contributed 10^7 and 10^8 atoms ^{36}Ar, respectively, while the mass spectrometer contributed another 10^7.

For our first test, we analyzed an unirradiated 3 mg quartz chip containing numerous inclusions. As it turned out, in most steps the gas released by the sample was much smaller than the instrumental background. A special calculation was necessary to correct for hydrocarbon (non-Ar) interferences at mass 36: hydrocarbon spectra were repeatedly measured and normalized to mass 41, which was also measured during the sample run. All corrected ratios critically depended on the exact hydrocarbon correlation diagrams, for which the statistics are still rather poor. The corrections typically introduce errors around $3 \cdot 10^6$ atoms ^{36}Ar, so that the resolvable $^{40}Ar_{xs}$ is at least 10^9 atoms. Resolution was best for extraction steps containing most gas: three out of eight T steps yielded significantly enriched ^{40}Ar/^{36}Ar ratios, up to 330, while



the other steps gave values indistinguishable from air. Concentrations of $^{40}Ar_{xs}$ (in 10^9 atoms) are shown in fig. 1, vs. sample T.

Conclusions. 1. Excess Ar was present in the hydrothermal fluid which deposited the quartz in the Pulchiana pegmatite. 2. Excess Ar appears to be released in two pulses: at low T, when fluid inclusions decrepitate, and at high T, when lattice sites are degassed. (Authors' abstract)

VINOGRADOVA, G.V., VINOGRADOV, A.N., IKORSKY, S.V., ELINA, N.A. and LEKHANOVA, O.G., 1988, Peculiarities of the fluid regime of ore-generating systems of the early Proterozoic rare-metal granites of the northeastern part of the Baltic Shield, <u>in</u> Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 53-60 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 436-437. (E.R.)

VIRGO, David, LUTH, R.W., MOATS, M.A. and ULMER, G.C., 1988, Constraints on the oxidation state of the mantle: An electrochemical and ^{57}Fe Mössbauer study of mantle-derived ilmenites: Geochimica Cosmo. Acta, v. 52, p. 1781-1794.

VISHNEVSKII, S.A. and POSPELOVA, L.N., 1988, Fluid regime of impactites: Dense inclusions in high-silica glasses and their petrologic significance: Acad. Sci. USSR, Siberian Div., Inst. Geol. & Geophysics Preprint No. 16, 53 pp. (in Russian; abstract by R.M. Prol-Ledesma).

Includes the following studies of inclusions in glass from the Popigai astrobleme:

<u>Sample from outcrop 622</u> - It contains many fluid inclusions, most of them are gas bubbles. Their distribution is not homogeneous, but concentrate in the high porosity areas, located close to the surface. However, some fluid inclusions can be also observed in the compact glass.

Size of the gas inclusions ranges from a few microns and tens of microns to 0.5 mm. They are spherical or elliptical and only a few show some deformation. There are traces of fast expansion, as some gas inclusions show the effects of expanding or even exploding.

Away from the porous areas, isolated gas inclusions were observed with an average size of 30-50 μm. They may be the remnants of P quartz fluid inclusions. Larger isolated inclusions (0.2-0.3 mm) may be the result of the shrinkage of the residual melt.

The gas P was measured for some inclusions, yielding values of 0.5, 1.7, 4.1 and 5.0 atm.

In this sample there are also two-phase gas-liquid inclusions with spherical or elliptical shape and 4-5 to 20-50 μm in size. The most dense have gas-liquid ratios reaching 1:10 - 1:15.

<u>Sample from outcrop 1308</u> - The composition of the inclusions in the glass from this sample varies from dense, all-liquid, through gas-liquid (with different gas/liquid ratios), to gas inclusions. In the liquid phase of some inclusions cubic or primatic crystals of an isotropic mineral were observed (NaCl?). High density inclusions have a gas-liquid ratio of $\geq$1:10 and often $\geq$1:3 or 1:5.

The T of first freezing was -90°C, eutectic T ranged from -24 -25 to -2.5°C and the melting T varied from -2.4 to -4.9°C. (Authors' abstract)

VLASSOPOULOS, D., WOOD, S.A. and MUCCI, A., 1988, The solubility and speciation of gold in aqueous solutions containing organic ligands at 25°C (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 81. Authors at Dept. Geol. Sci., McGill Univ., Montreal, Quebec, H3A 2A7, Canada.

The solubility of Au has been measured at 25°C in a number of solutions of organic acids (oxalic, acetic, phthalic, benzoic and salicylic) in 0.1 M aqueous $NaClO_4$ over the pH range 3-12 and ligand concentrations up to 0.1 M.

Eh, pH, and total dissovled Au were measured after equilibration and (pre-log$[Au]_T$) was regressed against (-log[L]) in order to evaluate n, the average ligation number, and E°, the standard potential (at 1 M ligand concentration) for the reaction: $Au(s) + nL^{m-} \rightleftarrows AuL_n{}^{1-m} + e^-$ for each ligand (L) studied. Solubilities up to 25 ppb Au in benzoate and salicylate, 15 ppb in oxalate, 5 ppb in phthalate, and <2 ppb in acetate solutions were measured.

The data indicate that Au(I) does not complex with oxalate and that oxalate may even reduce Au(I) to Au° ($\bar{n} = -0.35 \pm 0.05$ for HL^- and -0.29 ± 0.04 for L^{2-}). No complexing was detected between Au and acetate ($\bar{n} = 0.07 \pm 0.37$) or phthalate ($\bar{n} = -0.02 \pm 0.02$ for HL^- and 0.12 ± 0.01 for L^{2-}). Complexing with phthalate may be inhibited by the chelation effect which would tend to deform the preferred linear coordination of Au(I). On the other hand, stable complexes appear to form between Au(I?) and benzoate ($\bar{n} = 3.05 \pm 0.50$), as well as the monoprotic form of salicylate ($\bar{n} = 4.27 \pm 0.51$). We conclude that isolated COO^- groups attached to benzene rings are likely sites for the complexation of Au onto the macromolecular organics, such as fulvic acids, in natural waters. (Authors' abstract)

von BARGEN, Nikolaus and WAFF, H.S., 1988, Wetting of enstatite by basaltic melt at 1350° and 1.0- to 2.5- GPa pressure: J. Geophys. Res., v.93, no.B2, p.1153-1158. First author at Max-Planck-Institut für Chemie, Mainz, FRG.

The results of partial melting experiments of olivine, enstatite, and basalt PG-16A at 1350°C and P from 1.0 to 2.5 GPa indicate that the melt wets enstatite with a dihedral angle of 20°-40° in the presence of small amounts of H_2O. The results of this study suggest that in the Earth's upper mantle the melt will occur largely in networks of interconnnected channels along the intergranular edges, where morphologies are controlled by thermodynamic equilibrium. The presence of enstatite will have no significant effect on the permeability of partially molten zones in the mantle, if small amounts of H_2O are present. (From the authors' abstract)

Von DAMM, K.L., 1988, Systematics of and postulated controls on submarine hydrothermal solution chemistry: J. of Geoph. Res., v.93, n.B5, p.4551-4561.

VOZNYAK, D.K., 1988, The transformation of inclusions of the mineral-forming medium and its genetic interpretation, in V.A. Kalyuzhnyi et al., eds., Geochemistry and Thermobarometry of Endogenic Fluids, Scientific Proceedings: Kiev, Naukova Dumka Press (ISBN 5-12-000435-0), p. 25-33 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 441. (E.R.)

VOZNYAK, D.K. and KVASNITSA, V.N., 1988, Unusual inclusions of mineral-forming media; inclusions of crystallized salt melt: Geokhimiya, 1988, no. 11, p. 1661-1664 (in Russian)

VOZNYAK, D.K., KVASNITSA, V.N., KHAR'KIV, A.D., LEGKOVA, G.V. and VOZNYAK, L.A., 1988, First find of the inclusion of saline magmatic solution into the crystals of kimberlite zircon: Mineralogicheskiy Zhurnal, v. 10, no. 4, p. 15-22 (in Russian).

VROLIJK, P.J., 1987, Paleohydrogeology and fluid evolution of the Kodiak accretionary complex, Alaska: PhD dissertation, Univ. California, Santa Cruz, CA.

See Vrolijk 1987a and 1987b, Fluid Inclusion Research, v. 20, p. 394-395. (E.R.)

VROLIJK, Peter, MYERS, Georgianna and MOORE, J.C., 1988, Warm fluid migration along tectonic melanges in the Kodiak accretionary complex, Alaska: J. Geophys. Res., v. 93, no. B9, p. 10,313-10,324. First author at Dept. Earth Sci., Univ. Cambridge, England.

Analyses of methane + water fluid inclusions from syntectonic quartz veins in melange boudins of the Kodiak accretionary complex, Alaska, indicate fluid T ranging from 215° to 290°C at depths between 10 and 14 km. These fluid T are significantly higher than those predicted by conductive heat flow models of subduction zones. Given the available geological constraints, this discrepancy is interpreted as the result of migration of warm fluids from deeper structural levels along active fault zones during subduction-related underthrusting of these units. This interpretation requires more careful consideration of how migrating fluids affect the general thermal structure of subduction zones. (Authors' abstract)

VRY, J.K. and BROWN, P.E., 1988, Fluid inclusions: Equivocal fluid evidence in high-grade metamorphic rocks (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A341-A342. Authors at Univ. Wisconsin-Madison, Madison, WI 53706, USA.

Fluid inclusions in rocks from the Pikwitonei granulite domain (PGD), north-central Manitoba, Canada, provide evidence that isolated, texturally primary fluid inclusions in granulite facies rocks are frequently not a reliable indication of peak metamorphic fluid compositions. Only if the primary, peak metamorphic fluid inclusions 1) could be consistently identified, 2) could be shown to have trapped representative samples of the prevailing peak metamorphic fluid, and 3) had retained those original compositions without later changes due to leakage, necking down, or reaction with enclosing host minerals, would direct applications of such fluid inclusion data be truly pertinent in modeling deep crustal processes.

The PGD is interpreted as an exposed oblique section of Archean crust and a rare example of a prograde amphibolite-granulite transition. On the whole, there is a trend from aqueous to carbonic fluid inclusion compositions with increasing metamorphic grade across the region. However, in detail many common features are problematic. In granulite facies country rocks, isolated texturally primary fluid inclusions frequently contain inappropriate peak metamorphic fluid compositions, or display a wide or ambiguous range of fluid densities. Thus, the only 'primary' inclusions in some granulite-facies metapelites are aqueous and highly saline, whereas other similar rock samples contain isolated low-density nitrogen inclusions. Even within the different minerals of a single rock, inclusion compositions can differ markedly. In a sapphirine-bearing granulite from Natawahunan Lake, adjacent 'primary' fluid inclusions in plagioclase show a nearly complete separation of aqueous and carbonic fluid phases and marked differences in the compositions of abundant, associated daughter salts. Coexisting sapphirine is characterized by CO_2 inclusions, generally without detectable H_2O or daughter salts; inclusions in orthopyroxene are frequently blackened by an opaque phase and contain at least one large birefringent daughter salt; garnets contain abundant, netted, necked-down CO_2-rich fluid inclusions with occasional birefringent daughter salts; and biotite crystals contain rare, small, probably saline aqueous inclusions. This wide range of 'primary' inclusion compositions, as well as common correlations of birefringent daughter salts with specific host minerals may relfect post-entrapment fluid-mineral reactions, differences in the rates of fracture healing, or multiple mineral growth histories. Although late, texturally secondary inclusions may prove more useful for constraining regional uplift histories, such applications could involve the same uncertainties described above. (Authors' abstract)

VUATAZ, Francois-D., GOFF, Fraser, FOUILLAC, Christian, and CALVEZ, Jean-Yves, 1988, A strontium isotope study of the VC-1 core hole and associated hydrothermal fluids and rocks from Valles caldera, Jemez Mountains, New Mexico: J. Geophy. Res., v.93, no.B6, p.6059-6067.

WAKE, B.A. and TAYLOR, G.R., 1988, Major's Creek, N.S.W., Australia - A Devonian epithermal gold deposit: Mineral. Deposita, v. 23, p. 239-246. Authors at Dept. Applied Geol., Sch. Mines, Univ. New South Wales, Kensington, N.S.W. 2033, Australia.

Mineralized veins at Major's Creek consist of preponderant quartz and carbonate gangue with Au. Au-Ag tellurides and base metal sulphides within silicified and sericitized dikes or granodiorite of the Braidwood Granite. Fluid inclusion studies indicate deposition throughout the range 350-80°C by low salinity fluids. Significant Au-Ag telluride mineralization took place at a T of about 155°C. Mineral deposition was due to the separation of a liquid CO_2 phase from an originally CO_2-rich aqueous fluid. Observed argillic alteration is a consequence of acid leaching above the boiling zone. Mineralization is epithermal in character and probably formed during the existence of a hydrothermal convective system. A relationship with similar epithermal Au deposits in the adjacent Eden-Yalwal Rift zone is inferred. (Authors' abstract)

WALL, V.J. and ETHERIDGE, M.A., 1988, Regional metamorphic fluid migration: Single pass or circulation? (abst.): EOS, v.69, p.464.

WALSH, J.F., KESLER, S.E., DUFF, Damien and CLOKE, P.L., 1988, Fluid inclusion geochemistry of high-grade, vein-hosted gold ore at the Pamour mine, Porcupine camp, Ontario: Econ. Geol., v. 83, p. 1347-1367. First author at The Golden Reward Mining Co., P.O. Box 888, Lead, SD 57754.

This study was undertaken to characterize fluid inclusions associated with high-grade, vein-hosted Au at the Pamour mine in the Porcupine camp of Ontario and to compare them with fluid inclusions in quartz veins associated with wall rock-hosted Au, which is much more common. The Pamour mine contains two principal types of ore bodies; metasediment-hosted fracture zones and larger metavolcanic or metasediment-hosted quartz-carbonate veins. Au in the veins is distributed erratically, attains very high grades locally, and increases in grade at higher levels. Zoned alteration around the veins is dominated by addition of K_2O, CO_2, As, S, and CaO and depletion of Na_2O. K_2O, CO_2, and S are concentrated in the hanging wall and the intensity of CO_2 and H^+ metasomatism increases upward in the mine, roughly parallel to the trend seen in Au values. Au was introduced, along with sphalerite, galena, calcite, chlorite, and chalcopyrite, late in the paragenetic history after brittle deformation of earlier vein-hosted quartz, tourmaline, feldspar, and pyrite. Sphalerite that is directly associated with high-grade Au contains two types of P inclusions: a CO_2-CH_4 fluid (20-45 mole % CH_4), and an H_2O-rich liquid with a carbonaceous phase (CO_2-CH_4) as well as muscovite and graphite dms. Aqueous phase salinity estimates range from 2 to 9 eq. wt % NaCl and SEM analyses of evaporitic residues of thermally decrepitated inclusions contain NaCl and $CaCl_2$, with lesser amounts of KCl, $MgCl_2$, S, Zn, and Fe. These two inclusion types appear to represent immiscible fluids trapped along the solvus in the $H_2O-CO_2-CH_4$-salt system at 325° ± 25°C and P of 1 to 2 kbars.

These fluids are similar to those observed in vein quartz at the McIntyre and Hollinger deposits, where most Au is hosted by wall rocks, except that CO_2 immiscibility appears to have been more widespread at Pamour. The separation of immiscible fluids of the type identified in this study would increase the fO_2 and pH of the residual fluid owing to the partitioning of H_2S, CH_4, and CO_2 into the carbonaceous phase. The net effect of these changes would be to decrease the solubility of bisulfide-complexed Au, suggesting that CO_2 immiscibility is an important contributor to Au deposition within veins where wall-rock interaction is limited. It is not clear whether all vein-hosted Au formed from such unmixing or only the higher grade ore shoots. (Authors' abstract)

WALTHER, J. and SCHOTT, J., 1988, The dielectric constant approach to speciation and ion pairing at high temperature and pressure: Nature, v. 332, p. 635-638.

WAN, Jiamin, NORMAN, D.I., ALBINSON, T.F. and GRUPO, Catorce, 1988, Gas analysis of fluid inclusions in Colorada and Sombrerete district, Zacatecas State, Mexico (abst.): Geol. Soc. Am. Abstr. with Programs, v. 20, no. 7, p. A354. First author at Geosci. Dept., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Bulk analysis of fluid inclusion volatiles within vein quartz has been carried out by mass spectrometry on Colorada and Sombrereta precious and base metal bonanza-type vein deposits in Mexico. The gas analysis data indicate the principal gas species are CO_2, H_2S, SO_2, H_2, N_2, CH_4 and organic species. The gas content of the fluid from Colorada is average 2.2 mole % ranging from 0.2 to 4.1 mole %, and for Sombrerete the average is 0.5 mole % ranging from 0.3 to 1.5 mole %. The total sulfur content of fluids for Colorada is 0.72 mole % which is much higher than for Sombrete 0.06 mole %. Organic species in the condensable gaseous phase includes ethene, propene, butane, and pentene. A possible source might be "humic acids." The fluid inclusion study indicates boiling solutions, Th range from 210 to 315°C for Colorada district and 150 to 260°C for Sombrerete district. Salinities of the two districts are similar and generally below 6 eq. wt.% NaCl.

Oxygen fugacity calculations based on the gas analyses indicate that the ore fluids in Sombrerete were more oxidized than the ore fluids in Colorada. The calculated solubilities of precious and base metals in the fluids indicate that these solutions were highly effective agents for transporting these metals. Comparing the presently active geothermal systems, inclusion fluids from barren veins, and the inclusion fluids from the ore veins there is a clear relationship between high level H_2S and precious metals.

The data from fluid inclusion study, T, salinity, and concentration of gas species are also used for a geochemical modeling, which shows how the ore solutions carry and precipitate the metals as the fluid chemistry changes. It also explains why and how H_2S is a chemical control for these deposits, and how the base metals, Ag and Au zones formed during the boiling or dilution process. (Authors' abstract)

WAND, U. and STRAUCH, G., eds., 1987, Isotope in nature: Proc. of Fourth Working Meeting, 1987, 704 pp.

Includes a paper by Makagon et al., on measurements of Rb, Sr and $^{87}Sr/^{86}Sr$ in fluid inclusions in quartz. (E.R.)

WANG, Anjian, 1988, A genetic model for veinlike gold deposits in paleocrust-with gold deposits in eastern Hebei craton as examples: Mineral Deposits, v.

7, no. 4, p. 16-26. Author at Changchun College of Geol., Changchun, Jilin, PRC.

The Au deposits in the craton might be classified into three types: Jinchangyu, Dushan and Yuerya. There exists no metallogenic specialization of host rocks and structures (faults) for different types of Au deposits. The H, O and Pb isotope data and the composition of fluid inclusions in quartz suggest that the ore-forming fluids responsible for all types of Au deposits are rather similar in chemical composition and other geochemical features and belong to a kind of special solution from the deep crust which has reached isotope equilibrium with its surrounding rocks. (From the author's abstract by E.R.)

WANG, Bixiang, LI, Dexing and ZHANG, Xijun, 1988, Brief on metallogenic conditions and genesis of the gold deposits in the Suichang-Longquan volcanic area: Bull. Nanjing Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., v. 9, no. 2, p. 45-54 (in Chinese; English summary).

Indexed under "Fluid Inclusions." (E.R.)

WANG, Bixiang and ZHANG, Yuanqi, 1988, Research on the composition of mineral melt inclusions in volcanic rock series in the Great Wall Station area, King George Island, Antarctica: Kexue Tongbao, v. 33, no. 23, p. 1962-1964 (in English). Authors at Inst. Geol., Chinese Acad. Geol. Sci., Beijing, PRC.

Raman analyses were made of the gas bubbles in melt inclusions in basalt for CO_2, H_2O, CH_4, and CO, from 5 intrusions. Microprobe analyses are also given of the glass and daughter mineral from one inclusion. The dm is probably in the series kirschsteinite-monticellite (near the former). The glass has 73.59% SiO_2. (E.R.)

WANG, Haishan, 1988, Geochemical characteristics and genetic discussion of the stratabound lead-zinc ore deposits in Fengtai, Shaanxi Province: Mineral Deposits, v. 7, no. 1, p. 54-63 (in Chinese; English abstract). Author at Northwest Inst. Geol. Min. Resources, CNNC, Xian, Shaangxi.

Studies show that inclusions in the minerals are mainly tiny fluid ones (2-3 μm), with no dms observed. Th for sphalerite and galena are between 200-300°C, their salinities are about 10%, and the fluid is of Ca^{2+}-Mg^{2+}-K^+-HCO_3^--Cl^--F^- type.

Galena is rich in As and poor in Sn; galena and sphalerite are comparatively high in Se; sphalerite is rich in Fe, Mn, Cu, Cd and poor in Ge, Zn; and the ore bodies are closely associated with Hg. All these characteristics suggest a high ore-forming T and the derivation of metallogenic materials from depths. Values for δS imply the probable addition of sulfur from depth. These and other data suggest that the ore deposits in this area are quite different from common sedimentary deposits, and also fail to show characteristics of typical magmatic-hydrothermal deposits. It is therefore concluded that these deposits should be of sedimentary-reworked type, with the repeated infiltration of the underground hot brine acting as the key reworking factor. (From the author's abstract)

WANG, Jianhua, ULMER, G.C., GRANDSTAFF, D.E. and FRIEL, J.J., 1988, Basaltic residuum glasses: An old and a new problem (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 81. First author at Geol. Dept., Temple Univ., Philadelphia, PA 19122, USA.

Bowen (1928) questioned whether the glassy residuum in basalts is rich in iron and silica. Others, e.g., Allen et al. (1985) found that mesostasis glasses from the Umtanum and Cohassett flows of the Columbia River Basalt (CRB) may even be of rhyolitic composition (SiO_2 61-73 wt.%). Friel et al.

(1985) studied residuum glasses in these same flows and found millimeter scale rectilinear Na-rich and K-rich segregations with a correlation coefficient of -0.76 between Na and K EDS X-ray maps of 51,200 pixels each. In Umtanum basalt glass, Kuo et al. (1986), using TEM, reported the existence of Fe-rich crystalline spheres (0.1 to 2.0 µm, total Fe as FeO of ca. 40 wt.%, CaO of ca. 13 wt.% and P_2O_5 of ca. 5.5%). In the present study, a preexamined polished section of Cohassett entablature was hydrothermally etched with synthetic CRB groundwater in a flow-through system (3.3 hrs., from 100-167°C at a flow rate of 72 ml/hr) and reexamined with computer-aided imaging of EDS maps. Similar Fe-rich spheres (0.5-2.5 µm, total Fe as FeO of ca. 32 wt.%, CaO of ca. 17 wt.%, and P_2O_5 of ca. 14 wt.%) were observed. In addition, the Na-rich and K-rich glass segregations are poor in iron (ca. 4.5 wt.%). SEM examination showed that during hydrothermal etching the K-rich glass dissolves faster than the Na-rich glass, particularly in proximity to spheres and spinel dendrites.

The existence of the spheres and the Na- and K-rich glass segregation indicates that there might be both liquid immiscibility and phase segregation in the cooling history of the basalt. Now, Bowen's (1928) skepticism of the assumption, "there are some basalts... in which the glassy residuum is of a brown color and this glass has been assumed... to be rich in iron" has been reconsidered. Relative to nuclear waste disposal in basalts, the redox capacity developed as residuum glasses dissolve demands new attention to the exact location and release rate of iron. (Authors' abstract)

WANG, S., TURNER, G. and BURGESS, R., 1988, An unusual ^{40}Ar-^{36}Ar age determination of illite encased in chert (abst.): Chem. Geol., v. 70, p. 18. Authors at Dept. Physics, Univ. Sheffield, S3 7RH, UK.

While studying argon released by crushing from fluid inclusions in cherts we made an unusual observation that large amounts of radiogenic ^{40}Ar and neutron produced ^{39}Ar (and ^{37}Ar) were released from one particular sample in a manner which suggested the presence of fluids with unrealistically high potassium and calcium concentrations. From the high concentrations as well as the Ca/K ratio it became apparent that the argon was being released from 1 to 10 micron sized illite grains encased in the chert. That the gas was released merely by crushing was surprising and suggested that the radiogenic ^{40}Ar as well as the neutron produced isotopes had diffused to the grain boundary and remained trapped there totally encased in chert until fracturing provided a means of escape. Precise multielement correlations between ^{40}Ar, ^{36}Ar, K and Cl indicate the presence of a well defined (K correlated) radiogenic ^{40}Ar component as well as a (Cl correlated) excess ^{40}Ar component, as is commonly found in hydrothermal fluid inclusions. The sample is a bedded chert in dolomite from the Jixian region, North China, and belong to the Dahoungyu Formation of the Changcheng System, Middle Proterozoic. The Dahoungyu Formation is composed of arkosic sandstone, tuffaceous sandstone, trachytic lava, and cherty dolomite. The age inferred from the crushing experiment correlation is 1100 Ma and is some 300 Ma younger than the age anticipated from the stratigraphic position of the sample. Stepped heating analysis will be carried out on the crushed residue in order to establish whether the age is an artifact. While the age has no major intrinsic significance it will be of interest to establish whether or not illite (and chert) can be reliably dated in this way. (Authors' abstract)

WANG, Xiuzhang and CHENG, Jingping, 1988, Major geological characteristics and origin of gold deposits in China (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 408-413. Authors at Inst. Geochem., Acad. Sinica.

Tabulates characteristics of the fluid inclusions representing six types of hydrothermal solutions forming Au deposits. (E.R.)

WANG, Zhenguang and ZHANG, Zixu, 1988, GUA and GUA1: PASCAL programs for the calculation of physicochemical parameters of chemical components in fluid inclusions: Mineral Deposit Data, p. 28-35 (in Chinese; translation by H.-Z. Lu). First author at Beijing Res. Inst. Min. Resources.

In this paper we describe a method, based on geochemical-thermodynamical principle, that can be used to calculate physicochemical parameters of the fluid during ore- rock-forming process.

After getting the data on the chemical components in fluid inclusions, the above parameters can be calculated using the following programs, GUA for fluid components and GUA1 for gaseous ones.

The programs are written in PASCAL language and follow a menu-driven format that is understood easily by anybody with little previous computer experience. When they are run, the following data have to be entered in turn: sample no., ore-forming temperature (PT), ore-forming pressure (P), component content, thermodynamic parameters, and quantity of sample, etc. After running, the physicochemical parameters can be calculated and printed out. These parameters are as follows: salt concentration (wt %), mineralizing concentration (M.C), reduction parameters (R), pH, Eh, gas fugacity (fH_2, fO_2, fCO_2, fCH_4, fCO), ratio of ions (Na/K, Na/Ca + Mg, F/Cl, CO_2/H_2O), and atom ratios (H:C:O:S:Cl), etc.

It is based on three hypotheses to calculate above parameters:

1. During the ore-forming and rock-forming process, fluid was kept in a closed system. A dynamic equilibrium existed among gaseous, liquid and solid phases.

2. The main components in inclusions are H_2, O_2, C and their compounds as well as solution of salts and water. Under the condition of high T and high P, they reacted with each other and a chemical equilibrium was established.

3. In ore-forming solution, a equilibrium should exist between the sum of equivalents for anions and cations.

The calculating formulas about different parameters have been deduced. (Authors' abstract)

WANG, Zhifen, 1986, Some problems on the mineralization of tin deposits in Gejiu, Yunnan: Proc. of Symp. on Mesozoic and Cenozoic Geol., China, Huang Jiqing, ed., Geol. Pub. House, Beijing, 1986, p. 609-620. Author at No. 308 Explor. Team, Southwest Geol. Explor. Co. MMT.

Gejiu Sn-deposits are large polymetallic Sn-bearing deposits, with cassiterite-sulfide and cassiterite-quartz mineralizations as the main types. Genetically these deposits are closely associated with the middle and late Yanshanian biotitic-granite. The K-Ar ages of granitic intrusions are 84-103 Ma and 64-80 Ma. The mineralization may be divided into four stages, with their formation T being 425°, 238°-358°, 277°-386°, and 290°-305°C respectively [F.I. data]; $\delta^{34}S$ mostly ranging from -2 - +15‰. The data of three Pb isotope samples are: $^{208}Pb/^{204}Pb$ = -18.43 - 18.67, $^{207}Pb/^{204}Pb$ = 15.62 - 15.80, and $^{208}Pb/^{204}Pb$ = 38.98 - 40.29. According to these data and to the studies of the regional geological setting and geologic features of the Sn-deposits, the author proposed a new metallogenic model for Gejiu Sn deposits. It is inferred that the Gejiu Sn deposits are related to the remelting of the lower crust and were emplaced to the shallow part of the crust. The cassiterite-quartz-type Sn-deposits were formed by fluids derived from a shallow source with short distance of transportation, while the cassiterite-sulfide-type Sn-deposits were formed through the precipitation of deep-source materials which underwent longer-distance transportation after their segregation. (Author's abstract)

Both decrepitation and Th data are given. (H.E.B.)

WANG, Zhitian and QIN, Kezhang, 1988, Geological-geochemical characteristics and metallogenic material sources of the Wunugetushan lower crust porphyry copper-molybdenum deposit: Mineral Deposits, v. 7, no. 4, p. 3-15. Authors at Beijing Inst. Geol. for Min. Resources, CNNC, Beijing, PRC.

Located in Manzhouli-Xinbaerhuyouqi area of Inner Mongolia, Munugetushan (called Wushan for short) is the locality of a large-sized porphyry Cu-Mo deposit. (...) The study of hydrogen-oxygen isotopes, REE geochemistry and fluid inclusions indicates that meteoric water began to enter at the early stage of alteration, and later gradually intensified its influence until it played the dominant role. (From the authors' abstract by E.R.)

WARES, R.P. and WILLIAMS-JONES, A.E., 1988, Lithostratigraphic controls on skarn mineralization in the northern Gaspe peninsula, Quebec: GAC, MAC, CSPG, AGC, AMC and SCGP Joint Annual Mtg., Program with Abst., v. 13, p. A132. Authors at Dept. Geol. Sci., McGill Univ., Montreal, Que H3A 2A7.

Copper skarn deposits of the northern Gaspe peninsula are associated with small tonalitic intrusions hosted by Devonian calcareous metasedimentary rocks. Controls on alteration and mineralization are related to the T of ore-forming fluids and carbonate/silicate ratios in the sedimentary protoliths. Contract metamorphism preceded hydrothermal alteration, enhancing lithostatic graphic control of calcareous units: pure limestones (>90 wt.% $CaCO_3$) were converted to marbles that host mineralized (1% Cu), laterally restricted magnetite-rich skarns. Magnetite is stabilized by high XCO_2 (>0.3) fluids resulting from calcite dissolution. Impure limestones produced porous calc-silicate marbles that were relatively permeable due to metamorphic devolatilization reactions. These units provided aquifers by hydrothermal fluids and host well-mineralized (1-4% Cu) stratiform grandite-clinopyroxene skarn. Calcareous pelitic rocks (<10% $CaCO_3$) were metamorphosed to calc-silicate hornfelses with low, fracture-controlled permeability. Widespread, alkali-altered hornfelses are bleached, barren or poorly mineralized (<0.5% Cu). Field relations and fluid inclusion microthermometry indicate that poorly mineralized, potassic hornfelses are associated with high-level, mineralized, moderate T skarns (400-600°C) whereas barren, sodic hornfelses are associated with deep-seated, barren, high T skarns (>600°C). The estimated $\Sigma\delta^{34}S$ of the ore fluids is 6-10‰. A model is proposed in which the interaction of magmatic fluids with host lithologies leached sedimentary sulfur and produced barren alteration zones at depth. Copper sulfides were precipitated at higher stratigraphic levels, at lower T within favorable lithologies such as porous calc-silicate marbles. (Authors' abstract)

WASSERBURG, G.J., 1988, Diffusion of water in silicate melts: J. Geol., v. 96, p. 363-367. Author at The Lunatic Asylum of the Charles Arms Lab., Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125.

The transport of water in silicate melts is examined from a theoretical point of view, taking into account the presence of both H_2O and OH^- species. It was assumed that only H_2O molecules may diffuse and that a constitutive relationship between the number density $n(H_2O)$ of H_2O molecules and the total water content (n_Σ) exists such that $n(H_2O) = g(n_\Sigma)$. This is related to dissociation or to chemical reactions such as H_2O molecular (melt) + Oxygen (melt) $\rightleftarrows$ 2 OH (melt). This approach leads to diffusion transport equations that are intrinsically nonlinear. Three regions are naturally defined: (I) high water content with a normal linear diffusion equation $\partial n_\Sigma/\partial\tau = D\nabla^2 n_\Sigma$, where D is the intrinsic diffusion coefficient of a H_2O molecule in the silicate; (II) an intermediate or transitional region where the transport equation is $\partial n_\Sigma/\partial\tau = D\nabla^2 g(n_\Sigma)$; and (III) a region of low water concentration where the transport equation is $\partial n_\Sigma/\partial\tau = D^*\nabla^2 n_\Sigma^2$. In the latter region, the equation is strongly nonlinear. D* is a constant diffusion coefficient related to D. It follows that the dissociation of water molecules to form OH^- in silicates automatically implies a nonlinear transport behavior due to the storage of dissociated water moleucles in immobile sites. This study of the kinetics of transport will aid in our understanding of speciation and structure in silicate melts. (Author's abstract)

WEARE, J.H. and MOLLER, Nancy, 1988, Solubility predictions in complex mineral systems (abst.): Amer. Chem. Soc. 196th Nat'l. Meeting, Abstracts (unpaginated). Authors at Dept. Chem., Univ. California, San Diego, La Jolla, CA 92093-0340.

Highly reliable models of natural waters have been developed for use in the prediction of mineral solubility. These models are based on the phenomenology of Pitzer and coworkers. They are capable of predicting solubility of naturally occurring minerals within experimental accuracy and for a range of concentration from 0.0 m to saturation (20 m). The model parameters are evaluated from binary and ternary experimental data. The model, however, can be applied to systems of high complexity. Recent research has extended the models to range from 25°C to 250°C. The talk will focus both on model development and the application of models to interpret natural mineral environments. Application of the models to complex environments has shown that natural waters models must be of high accuracy in order to reliably predict mineral assemblages. Our results show that such accuracy may be obtained for even systems with very complex chemistry (e.g., the borate system) if a sufficient data base is available and if sufficient attention is paid to model construction. (Authors' abstract)

WEBSTER, J.D., GILLEN, G., and SIMONS, D.S., 1988, Lithophile element transport in Cl- and F-bearing magmatic hydrothermal fluids derived from highly differential granitic magmas: Chlorophile vs. fluorophile elements (abst.): EOS, v.69, p.515-516. First author at Mail Stop 959, USGS, Reston, VA 22092.

Highly differentiated granitic rocks, such as ongonites, topaz rhyolites, A-type granites, Li-mica granites, and some rare-element pegmatites exhibit extreme enrichments in F, Cl, and lithophile trace elements, and are associated with ore deposits of lithophile elements (Mo, W, Sn, U, Be, Nb, REE) in variable combinations. The association of Cl-rich fluid inclusions and F-bearing gangue minerals with these ore deposits suggests that Cl- and F-bearing fluids transport the ore metals from the granites; however, experimental evidence of specific lithophile-halide complexes is limited. To demonstrate the effect of Cl and F on the aqueous transport of Li, Rb, Cs, Y, Ce, Nb, Ba, Sr, and Be in magmatic hydrothermal fluids, we conducted fluid-melt trace-element partitioning experiments at natural trace-element abundance levels. We used internally heated pressure vessels at 2 kbar and 800°C. Starting materials were topaz rhyolite+H_2O+silica, AgCl, and AlF_3 with or without NaF. The A/CNK molar $Al_2O_3/(CaO+Na_2O+K_2O)$, of the topaz rhyolite is 1.0 (G.C.A., v.51, p.389-402). Lithophile element concentrations of the starting material and the run product glasses were determined by ion microprobe.

For equilibrium with a peraluminous topaz rhyolite melt, we find the concentrations of Li, Rb, Cs, Y, Ce, Sr, Ba, and Nb increase in the fluid as Cl increases (maximum molality of Cl in the fluid=6), the alkalis (M) complex as MCl^0 in the fluid, and Ce may complex with Cl in a 1 to 3 ratio. We identify the lithophile-$(Cl, F)_n$ complexes as those giving the best fit in plots of the distribution coefficient versus (molality of F, Cl in fluid)^n. We also find the concentrations of Be, Y, Cs, Ce, Sr, and Nb in the fluid increase as F increases (maximum molality of F in the fluid=11). We varied the A/CNK, independently, from 0.4 to 1.6 in one set of experiments with ≥6 wt % F in melt; as A/CNK increases Be, Y, Cs, Ce, Sr, and Nb partition more strongly in favor of the fluid. (Authors' abstract)

WEBSTER, J.D. and HOLLOWAY, J.R., 1988, Experimental constraints on the partitioning of Cl between topaz rhyolite melt and H_2O and $H_2O + CO_2$ fluids: New implications for granitic differentiation and ore deposition: Geochimica Cosmo. Acta, v. 52, p. 2091-2105. First author at Dept. Geol., King's Bldgs., West Mains Road, Edinburgh, Scotland EH9 3JW.

The partitioning of Cl between superliquidus melts of topaz rhyolite and fluids consisting of H_2O and $H_2O + CO_2$ has been determined experimentally at P of 0.5 to 5 kbar and T of 725° to 950°C with fO_2 controlled near NNO. The major element and Cl contents of a starting material glass and the run product glasses were determined by electron microprobe. The concentration of Cl and the major elements in the fluid are calculated by mass balance.

Cl partitions in favor of the fluid for all experimental run conditions. For natural abundances of Cl in a magmatic system, (<2000 ppm Cl in melt and <40 g Cl/kg fluid), D_{Cl} ranges from 2 to 20. These values are much lower than those previously reported in the literature. D_{Cl} increases as the Cl content of the melt and fluid increases, as the F content of the system decreases, as T and P increase, as the melt becomes more peraluminous, and as $(H_2O/H_2O + CO_2)$ of the fluid increases. Peraluminous granitic melts that are in equilibrium with aqueous fluids at 800°C and 2 kbar achieve a maximum concentration of Cl in the melt at 2500 ± 100 ppm Cl (independent of the F content). In experiments with Cl ranging from 40 to 300 g Cl/kg fluid (2000 to 2500 ppm Cl in melt) the D_{Cl} ranges from 20 to 130 and is consistent with literature values.

The experimental data also provide strong constraints on the speciation of Cl in granitic melts and coexisting fluids. As a topaz rhyolite melt that contains <2500 ppm Cl equilibrates with HCl-enriched solutions, Cl is dissolved into the melt and H^+ exchanges with the cations Na, K and Fe, which leave the melt as chloride complexes. During the equilibration of HCl-enriched fluids with melts that contain >2500 ppm Cl, no additional Cl dissolves into the melt and no additional Na, K or Fe are removed from the melt. HCl does not become a dominant fluid species until the melt achieves the solubility maximum for Cl.

For fluid-saturated, silicic melts of granite composition with H_2O activities near 1, the strong partitioning of Cl into the fluid also causes partitioning of some ore metals, trace elements and the major elements Na, K and Fe(± Ca) into the fluid: This is maximized for granitic melts that are strongly peraluminous, low in F and highly enriched in Cl; partitioning of Cl into aqueous fluids is maximized at high P and T. If the H_2O-rich fluid is diluted with CO_2 $(X^{fl}(H_2O) > 0.45)$ the concentration of Cl in the fluid decreases strongly. (Authors' abstract)

WEBSTER, J.G., 1988, Thio complexes of arsenic in low temperature hydrothermal fluids (abst.): Terra cognita, v. 8, p. 183. Author at Chem.

Div., Dept. Sci. & Industrial Res., Petone, New Zealand.

The solubility of orpiment in oxygen-free, reduced sulphur-bearing solutions of pH 0.5-7.0 has been measured at T of 25°C and 90°C. In acid solutions, arsenious acid (As(OH)$_3^0$) is the predominant dissolved arsenic species, and reacts with added sulphide to precipitate orpiment according to the reaction: $2AS(OH)_3^0(aq) + 3H_2S(aq) = As_2S_3(s) + 6H_2O$.

Arsenic solubility at pH >4 is attributed to the formation of complexes comprising both hydroxyl and bisulphide ligand groups. Orpiment solubility is enhanced in the presence of sulphide only at near-neutral pH, where the proportion of sulphide existing as reactive bisulphide ion is relatively high. A solubility constant for orpiment, and cumulative stability constants for the complexes considered most compatible with the solubility data, have been calculated at 25°C and 90°C.

The experimental solubility of orpiment in near-neutral fluids is similar to the arsenic concentrations measured in active geothermal systems. In Champagne Pool, for example, the concentration of arsenic at equilibrium with sinter precipitates of orpiment and stibnite, is consistent with calculated arsenic solubility as thio-hydroxyl complexes. (Author's abstract)

WEDEKIND, Richard, LARGE, Ross, ZAW, Khin, HORVATH, Harry and GULSON, Brian, 1988, The composition and source of ore depositing fluids in the Tennant Creek gold field (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 492-494. First author at Geol. Dept., Univ. Tasmania, GPO Box 252C, Hobart, Tas. 7001.

Quotes literature data on fluid inclusion studies and new δD and $\delta^{18}O$ data. (E.R.)

WEINBERG, Andrew, 1987, Fluid inclusions in Prairie Evaporite halite: The composition of Devonian sea water and the evolution of the Elk Point basin of central Canada: MA thesis in Geol., Harvard Univ., Cambridge, MA.

Analyses of single fluid inclusions in halite from the Middle Devonian Prairie Evaporite of Saskatchewan show chemical trends during evaporative concentration which are rather different from those accompanying the simple concentration of modern sea water. These differences can be explained in terms of syndepositional reactions of the brine with earlier formed evaporite minerals and with non-evaporitic material present in the basin, without involving any differences between the composition of Devonian and modern sea water. During the formation of dolomite from calcite, Mg was exchanged for Ca in the brines. Subsequent anhydrite precipitation removed almost all sulfate from solution. All of the analyzed fluid inclusion brines are virtually sulfate-free, and have a Mg/Ca ratio considerably below that of sea water; both observations are consistent with extensive dolomitization. Other reactions have removed up to about 20% of the Na initially present in the sea water. The Na loss was balanced primarily by a Ca increase, which further reduced the Mg/Ca ratio and the sulfate concentration of the brines. Albitization of detrital feldspars and clays, followed by $CaCO_3$ dissolution appears to be the most likely mechanism for the exchange of Na for Ca. K has also been lost from the fluid inclusion brines, presumably by reactions forming authigenic microcline. However, analyses of brine seeps from the ore horizon in several potash mines in Saskatchewan show no loss of K from the brines during halite precipitation. Apparently, not all of the fluids responsible for the Prairie Evaporite were affected by these reactions.

The Li content of the largest inclusions analyzed suggests that a twofold increase in the concentration of the element accompanied the loss of Na and K from the brines. Li was probably released into the brines during the conversion of clay minerals to authigenic feldspars. (Continued)

Our data are consistent with the proposition that the composition of Devonian sea water was essentially identical to that of present day sea water. However, some differences in the composition of Devonian and modern sea water cannot be ruled out on the basis of our data. (Author's abstract)

WIENS, R.C., 1988, What we think we know from noble gases in shergottite EETA 79001: Papers presented at the 51st Ann. Mtg. of Meteoritical Soc., LPI Contrib. 665, p. 9.

Indexed under "Fluid Inclusions." (E.R.)

WEISBROD, A., 1988, Chemical composition of hydrothermal fluids buffered by vein- and pegmatite-forming mineral assemblages: An experimental calibration at high temperatures and pressures (abst.): Chem. Geol., v. 70, p. 166. Author at ENSG-CRPG, BP 452, 54001 Nancy cedex, France.

Among the intensive parameters that control the mechanisms of dissolution, transport and deposition in aqueous media, the compositions of hydrothermal fluids are of major interest. At the moment, no analytical technique provides reliable estimates of the concentration of solutes in individual fluid inclusions. However, these compositions can be derived from equilibrium between the fluid and a convenient mineral assemblage (buffer). Examples of experimental calibration of such equilibria are presented hereunder; they involve chemical species related to specific environments such as hydrothermal veins and pegmatites.

Modelling the metasomatic changes in ultramafic rocks during their alterations requires reliable equilibrium constants. These constants have been determined at 350 and 600°C, 1 kbar, in the system MgO, SiO_2-H_2O-HCl, for the following assemblages (excess fluid):
350°C: Q-Tc, K = 5.9; Tc-Chrys, K = 7.1; Chrys-Brucite, K = 8.0
600°C: Q-Tc, K - 0.6; Tc-Biopyribole, K = 1.0; Biopyr.-Fo, K = 2.0

Because of the good precision of the obtained K values, thermochemical data for solid and fluid species can be calculated with a much better accuracy than calorimetry.

Partition of Ca and Mn between aqueous chloride solution and tungstates has been determined at 1 kbar, 300 to 600°C. The Mn/Ca ratio increases exponentially with T and the total chloride content. This effect of molality is interpreted in terms of complexing and fluid unmixing.

Partiton of fluorine between aqueous solution and F-OH phlogopite confirms the very strong partition of F towards the solid. At 700°C, 2 kbar, experiments yield the quasi-linear relation $X_{FH}(aq) = .6 \times 10^{-3} X_F(mica)$, for $X_F(mica) < .5$. Higher contents of fluorine in fluids are expected with the quartz-topaz-andalusite buffer. However, the reaction rates in this system are very low, even at high T.

Tourmaline is considered as a very "refractory" mineral. The boron content of aqueous fluid equilibrated with tourmaline + cordierite or clinochlore + andalusite or pyrophyllite + albite + quartz has been determined at 1 kbar, from 350 to 730°C. For the pure Mg end-member, the mass fraction of B_2O_3 in solution increases from $.5 \times 10^{-3}$ (350°C) to 22×10^{-3} at 720°C; melting occurs at about 730-740°C. For the pure Fe end-member, the B_2O_3 content of the fluid is slightly below that obtained with the Mn end-member; melting occurs at about 100°C below that measured for Mg. The P effect is negligible between 1 and 4 kbar. During the course of these experiments, the presence of a Cl-B complex has been recognized. These results are used to model the transfer of boron in aqueous fluids and tourmalinization processes at high T and P. (Author's abstract)

WELHAN, J.A., 1988, Methane and hydrogen in mid-ocean-ridge basalt glasses: analysis by vacuum crushing: Can. J. Earth Sci., v.25, p.38-48.

Author at Isotope Lab., Scripps Inst. Oceanog., La Jolla, CA 92093, USA.

A comparative study of vacuum crushing methods for analyzing reactive gases in basaltic glasses shows that ball milling is an efficient means of releasing occluded gases but that blank production represents a potentially serious problem that must be accounted for when determining reactive-gas compositions. Production of H_2 and CH_4 in a stainless-steel ball mill in the absence of rock material increases with length of crushing time. However, test results presented here indicate that blank levels are reduced during the actual crushing process by the presence of rock powder, which may act as a cushion to reduce metal-metal contact. Crushing in copper tubes under a hydraulic press produces no blanks for these gases, but crushing efficiency and gas release are very low, and gas absorption on rock powder becomes a significant problem. Experiments with methane adsorption on crushed basalt suggest that the loss of methane is a chemisorption process that is, for the most part, irreversible.

Applying corrections for these effects, we find that H_2/CH_4 ratios (≈3-30) in mid-ocean-ridge basalt glasses are similar to those seen in high-T mid-ocean-ridge hydrothermal fluids. These data, arguments based on the similarity of water/rock mass ratios calculated from basalt gas data, and the uniformity of CH_4/He ratios in divers high-T mid-ocean-ridge hydrothermal fluids support the contention that dissolved CH_4 and H_2 in these fluids are predominantly derived from leaching of mid-ocean-ridge basalt. (Author's abstract)

WELLS, J.T. and GHIORSO, M.S., 1988a. The influence of reaction kinetics and fluid flow on the concentration of silica in hydrothermal fluids (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A96. Authors at Dept. Geol. Sci., AJ-20, Univ. Washington, Seattle, WA 98195.

We examine the influence of fluid flow and quartz reaction rates on the concentration of dissolved silica using a computer model that simulates the kinetics of water-rock interaction in hydrothermal systems. The algorithm provides a numerical solution to the non-linear reaction-advection equation that describes the change in concentration of silica with respect to time and space. The model allows us to quantify the influence of the fluid velocity, the ratio of reactive rock surface area to fluid volume, and the geothermal gradient on attainment of equilibrium in different parts of a hydrothermal system. Solubility data are calculated using the method of Fournier (1983) and Fournier and Marshall (1983); kinetic data are from Rimstidt and Barnes (1980). This study builds upon the methods of Lasaga (1984) by addressing systems exposed to a T gradient.

We test the validity of the quartz geothemometer/geobarometer under varying hydrothermal conditions with the model. Quartz geobarometry/geothermometry relies on the assumption that quartz and hydrothermal fluid reach equilibrium at depth and that quartz does not subsequently dissolve or precipitate along the path of fluid flow. For this assumption to be true, the reaction between quartz and fluid must be so slow that reequilibration does not occur as the fluid encounters new T-P conditions.

Our calculations verify that in cases with high fluid velocity, low ratio of rock surface area to fluid volume, and T below about 200°C, the assumption is generally valid. However, in mid-ocean ridge hydrothermal systems--where fluid T often reaches 350°C--reaction rates are so fast that measurable exchange between fluid and rock is predicted to occur. Therefore, the quartz geothermometer/geobarometer may yield incorrect results.

Another complication is revealed by examining a system in which hydrothermal fluid reacts simultaneously with quartz and amorphous silica. Dissolved silica in this type of solution may be maintained at a nonequilibrium steady-state concentration intermediate between that expected from equilibrium with only quartz or only amorphous silica. By taking into consideration this type of kinetic interference it is possible to more accurately describe the controls on the concentration of silica in hydrothermal fluids. (Authors' abstract)

WELLS, J.T. and GHIORSO, M.S., 1988, Rock alteration, mercury transport, and metal deposition at Sulphur Bank, California: Econ. Geol., v. 83, p. 606-618. Authors at Dept. Geol. Sci., Univ. Washington, Seattle, WA 98195.

The hydrothermal alteration at Sulphur Bank, Lake County, California, is characterized by the phases alunite, kaolinite, and amorphous silica. Comparison between the observed mineralogical zonation and theoretical simulation of the water-rock interaction reveals that the alteration process at Sulphur Bank may be described on a broad scale in terms of an irreversible thermodynamic model based on the assumption of local equilibrium. However, this theoretical model alone fails to explain the details of the mineralogical zonation of the veins and alteration halos at Sulphur Bank. The zonation may be the result of a coupled reaction-fluid transport system in which two solute transport mechanisms--advective flow through open veins and diffusion--build superimposed alteration sequences.

As a result of aqueous Hg-complex stability studies, it is inferred that Hg is transported as sulfide complexes at Sulphur Bank. In spite of the common association of Hg and organic matter in some hydrothermal systems, newly compiled thermodynamic data indicate that organic Hg complexes are unstable under reducing conditions typical of hydrothermal systems.

Both boiling and oxidation are effective depositional processes for cinnabar according to theoretical calculations presented here. Oxidation best fits the geologic characteristics of the near-surface mineralization of Sulphur Bank, although boiling may be responsible for deeper mercury and possible Au mineralization. (Authors' abstract)

WEST, T.S. and NURNBERG, H.W., eds., 1988, The determination of trace metals in natural waters: International Union of Pure & Applied Chem., Anal. Chem. Div., Blackwell Sci. Pub., 362 pp.

Section 1 provides individual reviews of the spectrophotometric and fluorimetric methods for Se, Cr, Zn, Cd, Pb, Ni, Co, Cu, and Mo. Section 2 covers atomic-, mass-, and X-ray-spectrometric (emission spectrometry, ICP, AAS, spark source mass spectrometry, XRF), EPR, and luminescence methods. Section 3 - voltammetric methods, and Section 4 INNA. Other sections cover pH, determination of trace metal complexation, etc. (E.R.)

WESTRICH, H.R., STOCKMAN, H.W., and EICHELBERGER, J.C., 1988, Degassing of rhyolitic magma during ascent and emplacement: J. of Geophy. Res., v.93, no.B6, p.6503-6511. Authors at Geochem. Div., Sandia Nat'l. Lab., Albuquerque, NM.

The degassing history of a rhyolitic igneous system was documented from analyses of drill core samples through the extrusive and intrusive portions of Obsidian Dome and of surface samples of associated tephra. The initial volatile composition of the Inyo magma was estimated to be 4.0 wt.% H_2O, 500 ppm F, 800 ppm Cl, and 80 ppm S. Retained volatile contents of glassy and crystalline samples reflect the effects of decompression and second boiling. Decompression is rapid and involves loss of water-rich fluid until a close approach to lithostatic equilibrium is achieved. Second boiling is a slower process and produces a chlorine-rich fluid, some of which can be trapped during development of extremely fine crystallization textures. Nearly complete dewatering during decompression of surface-extruded magma strongly undercools the system ($\Delta T \approx 175^\circ C$), suppressing crystallization and yielding glassy rhyolitic lava. Partial degassing of shallowly intruded regime is the zone of maximum volatile release because second boiling is incomplete in extrusives, and volatile-bearing crystalline phases are stable in magma crystallized at greater depth. (Authors' abstract)

WHEAT, C.G. and CARPENTER, Roy, 1988, $MnCl^+$ and $MnSO_4$ association constants to 170°C: J. Solution Chem., v. 17, no. 5, p. 467-480.

WHELAN, J.F., COBB, J.C. and RYE, R.O., 1988, Stable isotope geochemistry of sphalerite and other mineral matter in coal beds of the Illinois and Forest City basins: Econ. Geol., v. 83, p. 990-1007. First author at U.S. Geol. Survey, Box 25046, Mail Stop 963, Denver Fed. Center, Denver, CO 80225.

Cleat and clastic dikes of Middle Pennsylvanian-age coal beds of the Illinois and Forest City basins of Illinois, Iowa, Missouri, and Kansas locally contain appreciable amounts of sphalerite within a kaolinite-pyrite-sphalerite(± pyrite)-calcite paragenetic sequence. The sphalerite and associated minerals are of interest as a partial record of the history of fluids in the sedimentary basin and as possible indicators of Mississippi Valley-type mineralization. Moreover, zinc from the sphalerite may represent an exploitable by-product of coal mining and combustion.

Pyrite is abundant in these coals both as fine-grained disseminated framboids that formed during early diagenesis and as coarser grained cleat fillings, etc., that formed much later. The $\delta^{34}S$ values of this later pyrite, the sphalerite, and the coal organic matter range from -12 to 19 per mil. Within individual samples, however, pyrite, sphalerite, and organic matter sulfur $\delta^{34}S$ values are nearly identical. This similarity strongly suggests related origins. The $\delta^{34}S$ values of pyrite, sphalerite, and organic matter from coals of the Illinois basin and the central and southern Forest City basin range from -12 to 0 per mil. This range is not unique to the sphalerite-bearing coals; pyrite and organic matter from sphalerite-free high sulfur coals have similar $\delta^{34}S$ values (Price and Shieh, 1979). We believe that sulfur produced by the breakdown of organosulfur compounds in the coal is incorporated into the epigenetic sulfides. In the northern Forest City basin, however, many samples have $\delta^{34}S$ values between 8 and 19 per mil. These are similar to the $\delta^{34}S$ values of sphalerite and pyrite from the Upper Mississippi Valley Zn-Pb district which lies northeast of the Forest City basin and north of the Illinois basin. This similarity suggests input from a Mississippi Valley-type hydrothermal system.

Cleat kaolinite has δD values of -36 to -24 per mil and $\delta^{18}O$ values of 19.2 to 20.2 per mil. Assuming that cleating postdated the lignite rank of coalification implies that kaolinite was deposited between 40° and 100°C. At the lower T, the kaolinite fluid would have had an isotopic composition similar to seawater; at the higher T, it would have had a composition similar to the sphalerite-depositing fluids. Sphalerite was deposited from a fluid that was chemically and isotopically similar to the fluids responsible for the main-stage ores of the Upper Mississippi Valley Zn-Pb district (75°-113°C, approximately 21 eq. wt % NaCl, δD = -65 to -3‰, and $\delta^{18}O$ = -0.9-9.9‰). The isotopic compositions ($\delta^{13}C$= -12.4 to -2.7‰ and $\delta^{18}O$ = 21.1-25.8%) and paragenetic positions of the cleat calcite samples are similar to those of the late-stage calcite of the Upper Mississippi Valley Zn-Pb and Illinois-Kentucky fluorspar districts. Calcite inclusion fluids had $\delta D(H_2O)$ values of -80 and -58 per mil, implying a meteoric water source. At probable T of 15° to 75°C, this calcite formed from fluids having calculated $\delta^{18}O(H_2O)$ values of -9 to 1 per mil, implying slight to moderate exchange with sedimentary rocks. The diagenetic-epigenetic history of fluids recorded by the cleat minerals probably began with a slightly evolved seawater, followed by a metal-bearing deep basin brine, and concluded with a cooler, slightly evolved, meteoric-water fluid. (Authors' abstract)

WHITE, Brad and MONTANA, Art, 1988, Viscosities of liquids in the systems $KAlSi_3O_8$-CO_2 and $KAlSi_3O_8$-H_2O at high pressures (abst.): EOS, v. 69, p. 1465. Authors at Dept. Earth & Space Sci. & Inst. Geophys. & Planet. Physics, UCLA, Los Angeles, CA 90024-1567.

To provide insights into the structures and transport properties of magmas, we measured the viscosities (η) of liquid $KAlSi_3O_8$ and liquids in the systems $KAlSi_3O_8$-CO_2 and $KAlSi_3O_8$-H_2O at 15, 20, and 25 kbar and 1500-1600°C using the falling-sphere method. At 1500°, log η of $KAlSi_3O_8$ decreases from 5.0 at 1 bar (Urbain et al., 1982) to 4.36 and 3.96 at 15 and 20 kbar, respectively, consistent with the negative $d\eta/dP$ of other highly polymerized liquids (uncertainty in η is 15%). However, log η increases isothermally to 4.23 at 25 kbar as the liquid stiffens as it approaches the P-T coordinates of the liquidus.

Adding 0.5 wt% CO_2 to the liquid produces an isothermal decrease in log η to 4.06, 3.79, and 3.41 at 15, 20, and 25 kbar and 1500°. An equimolar amount of H_2O (0.205 wt%) more effectively reduces log η to 3.45, 3.40, and 3.34 at the above conditions. The viscosities of our liquids have a negative T dependence, with H_2O and CO_2 producing nearly equal reductions in viscosity at 1500 and 1600°. These data indicate that H_2O and CO_2 depolymerize $KAlSi_3O_8$ liquid by breaking bridging oxygen bonds to form OH^- and CO_3^{2-}, similar to the mechanism in H_2O- and CO_2-bearing $NaAlSi_3O_8$ liquids. The greater effectiveness of CO_2 in reducing η of $KAlSi_3O_8$ relative to $NaAlSi_3O_8$ at 25 kbar indicates that the former liquid dissolves a larger proportion of total carbon as CO_3^{2-} than the latter. This is consistent with our published feldspar-CO_2 phase equilibria.

At 20 and 25 kbar and 1500°, log η decreases to 2.30 as H_2O increases to 2.0 wt%, with a highly positive $d^2\log \eta/dX^2$. In contrast to $KAlSi_3O_8$-H_2O, $KAlSi_3O_8$-CO_2 exhibits a minimum in η between 0.5 and 1.0 wt% CO_2 at 20 kbar and 1.0 and 1.5 wt% at 25 kbar, perhaps reflecting a concentration-dependent speciation of CO_2 as observed by Stolper (1982) for H_2O, or a change toward non-Newtonian behavior as the liquid becomes saturated with carbon. (Authors' abstract)

WHITNEY, J.A., 1988, Composition and activity of sulfurous species in quenched magmatic gases associated with pyrrhotite-bearing silicic systems: Econ. Geol., v. 83, p. 86-92.

WICKHAM, S.M., 1988a, Underplating, anatexis, and assimilation of metacarbonate: A possible source for large CO_2 fluxes in the deep crust (extended abst.): J. Geol. Soc. India, v. 31, no. 1, p. 162 (also in Workshop on the Deep Continental Crust of South India, L.D. Ashwal, ed., LPI Tech. Rept. 88-06, p. 188).

See also next item. (E.R.)

WICKHAM, S.M., 1988b, Underplating, anatexis, and assimilation of metacarbonate: A possible source for large CO_2 fluxes in the continental crust (abst.): EOS, v.69, p.467. Author at Dept. of Geophy. Sci., Univ.

of Chicago, Chicago, IL 60637.

Models for granulite petrogenesis require a heat source to generate the high crustal T associated with granulite grade metamorphism and associated anatexis. This most likely takes the form of mantle-derived basaltic magma that is underplated beneath or intruded into the lower continental crust. Such underplating will cause rapid, large-scale melting of the overlying roof rock. Refractory rocks within the melting zone (such as metacarbonates that are a common minor constituent of deep crustal granulite terranes) will not melt but may sink into the underlying mafic magma, and would in any case experience very high temperatures (900-1200°C). This in turn would promote very high temperature decarbonation, generating sudden, large fluxes of CO_2-rich fluid that would be released upward through the anatectic zone into the overlying crust. Such a process may explain many petrological features of granulite terranes where CO_2 infiltration is thought to be important without requiring a mantle-derived CO_2 flux. It may also be the underlying cause of commonly observed surface emanations of CO_2 at volcanic centers associated with extensional tectonism. The isotopic composition of such emanations, and of CO_2-rich fluid inclusions in granulites, is readily interpretable in terms of derivation from deep-seated carbonate rocks that have already experienced a metamorphic history. Whether or not CO_2 flushing occurs during granulite metamorphism may simply reflect the presence or absence of carbonate rocks at deep crustal levels. CO_2 fluxes generated in this way may be a natural consequence of crustal growth processes involving underplating of basalt beneath a carbonate-bearing lower crust. (Author's abstract)

WIENS, R.C., 1988, On the siting of gases shock-emplaced from internal cavities in basalt: Geochimica Cosmo. Acta, v. 52, p. 2775-2783.

WIENS, R.C. and PEPIN, R.O., 1988, Laboratory shock emplacement of noble gases, nitrogen, and carbon dioxide into basalt, and implications for trapped gases in shergottite EETA 79001: Geochem. Cosmo. Acta, v.52, p.295-307.

WIGHTMAN, R.M., 1988, Voltammetry with microscopic electrodes in new domains: Science, v. 240, p. 415-420. Author at Chem. Dept., Indiana Univ., Bloomington, IN 47405.

Voltammetric electrodes of microscopic dimension, termed ultramicroelectrodes, can be used to make measurements that are difficult or impossible with conventional electrochemical techniques. Measurements of chemical concentration can be made with these electrodes on a microsecond time scale and with micrometer spatial resolution. In addition, measurements can be made in highly resistive solutions. (Author's abstract)

Although mostly used in other disciplines, the techniques of manufacture and use of these ultramicroelectrodes may be applicable to fluid inclusions. (E.R.)

WILDE, A.R. and BLOOM, M.S., 1988, Transport and deposition of gold with uranium and platinum-group elements in unconformity-related uranium deposits (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 22, p. 325-330. Authors at Monash Univ., Clayton 3168, Victoria, Australia.

Quotes fluid inclusion data from the literature (Wilde et al., 1988). (E.R.)

WILKERSON, Gregg, DENG, Qingping, LLAVONA, Ramon and GOODELL, Philip, 1988, Batopilas mining district, Chihuahua, Mexico: Econ. Geol., v. 83, p. 1721-

1736. First author at U.S. Dept. Interior, Bureau of Land Management, 800 Truxtun Ave., Room 311, Bakersfield, CA 79968.

The Batopilas mining district is one of the few mining districts where the major ore mineral is native Ag. The native Ag occurs as fissure vein deposits in granodiorite, fine-grained diorite, and dacite. Ore bodies are irregularly shaped pods of massive native Ag in calcite and may contain up to 75 wt % Ag. Three types of wall-rock alteration are found with the Ag mineralization: (1) chlorite-actinolite alteration, (2) silicification, and (3) pyritization. Chlorite-actinolite alteration is often associated with gray and green argillization. The host rocks of many, but not all, ore bodies have experienced chlorite-actinolite alteration and pyritization. Silicification occurs in dikelike masses within the Dolores and Pastrana units. These silicified zones are generally less than 9 m wide. Pyritization is found in the intrusions. Minor quartz-pyrite veins are found throughout. Gangue in the Batopilas ores is calcite and is associated with small amounts of sphalerite, galena, and laumontite. Cobalt-nickel arsenides and ruby silvers have been reported, but their presence is not confirmed by this investigation. Pyrite is abundant in the host rocks but is absent from the ores.

A well-developed pattern of mineralogic zonation exists in the district. This zonation is concentric around the Tahonas porphyry Cu deposit. Preliminary fluid inclusion studies document Th between 217° and 434°C, and salinities over 20 eq wt % NaCl for quartz from the Tahonas porphyry Cu deposit. Studies on quartz from outlying regions give Th ranges of 224° to 351°C, and salinities of from 9 to 18 eq wt % NaCl. Studies of the later generation of calcite, Ag, and minor sulfides give Th values between 137° and 257°C for calcite and 170° to 196°C for sphalerite. Salinities in calcite are concentrated between 7.6 and 13.2 eq wt % NaCl.

The estimated 300 million oz (9.3 million kg) of Ag produced to date probably was deposited from circulating connate waters adjacent to the Tahonas porphyry Cu mineralizing system. (From the authors' abstract by E.R.)

WILKINS, R.W.T., HLADKY, G. and WILMSHURST, J.R., 1988, Laser micro-Raman spectroscopy - A new tool for exploration geochemistry (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 580. Authors at CSIRO Div. of Explor. Geosci., P.O. Box 136, North Ryde, N.S.W. 2113.

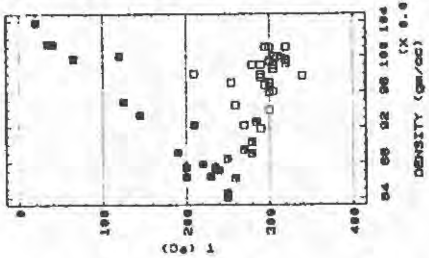
A review of the importance of laser Raman to fluid inclusion studies and to determine the degree of maturity of organic matter in sediments. (E.R.)

WILKINSON, W.H., WENDT, C.J. and DENNIS, M.D., 1988, Gold mineralization along the Riverside Mountains detachment fault, Riverside County, California, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 487-504. Authors at NICOR Mineral Ventures, Inc., 2341 S. Friebus, Suite 12, Tucson, AZ 85713.

Full paper for abstract in Fluid Inclusion Research, v. 20, p. 406, 1987. (E.R.)

WILLIAMS, A.E., 1988a, Fluid density distribution in a stratified geothermal reservoir: Salton Sea geothermal system, California (abst.): Geol. Soc. Am. Abst. with Programs, v. 20, no. 7, p. A98. Author at Geothermal Resources Program, IGPP, Univ. California, Riverside, CA 92521.

A sharp interface between fluids of distinctive salinity, chemistry, isotopic composition and T has been delineated in the Salton Sea geothermal system (SSGS). Low T (<260°C) low TDS (typically <10 wt %) fluids (solid squares) overlie the typical SSGS hypersaline brines which have up to 26 wt % TDS (open squares). Chemical analyses and T and P data concerning more than 60 intervals producing geothermal fluids were used to generate a reservoir fluid density distribution for the SSGS, using approximations of fluids as Na-Ca-K-Cl solutions. Densities in the system vary from less than 0.85 gm/cc to at least 1.02 gm/cc. The high densities are found at both the lowest T (shallow, dilute fluids) and at the highest T (deep, hypersaline brines). At intermediate T near to the proposed brine interface, lower salinities and relatively high T (200 to 280°C) create a low density reigon within the hypersaline brine reservoir. The stable density stratification of the explored, economic (hypersaline) portion of the reservoir prevents convective mass transport across the fluid interface and provides a mechanism producing the conductive thermal gradients observed in the SSGS that is unrelated to the host rock lithology. Convection in the shallow, cool fluids (<200°C) overlying the interface, however, should be possible if the shallow, relatively unconsolidated sediments are sufficiently permeable. (Author's abstract)



WILLIAMS, A.E., 1988b, Delineation of a brine interface in the Salton Sea geothermal system, California: Geother. Resources Council, Transactions, v. 12, p. 151-157. Author at Geothermal Res. Program, Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521, USA.

Fluids in the Salton Sea geothermal system (SSGS) cluster into two distinct populations in terms of their salinity. The hot, hypersaline brine for which the SSGS is known, is overlain by a cooler (<260°C) fluid with distinctly lower salinity. Both types of fluid are produced from closely spaced production intervals in geothermal wells, indicating that a sharp salinity interface exists over much of the field. Sedimentary features are typically crosscut by the fluid interface, which parallels the elongate dome-like thermal structure of the SSGS. The fluid interface occurs in portions of the reservoir where T are ≃260°C. Hypersaline brines have densities of ~ 1.0 gm/cm^3, while the low TDS fluids have densities as low as .85 gm/cm^3. The stable, density-stratified interface implied by the data should act as a barrier to convective heat and mass transfer in the SSGS, isolating the hypersaline reservoir from overlying dilute fluids. (Author's abstract)

WILLIAMS-JONES, A.E. and SEWARD, T.M., 1988, The stability of calcium chloro-complexes in aqueous solutions at temperatures between 100° and 360°C. (abst.): GAC/MAC Program with Abstracts, v.13, p.A135.

WILSON, Lorelei and McGEE, William, 1988, Construction and calibration of a demountable poor microscopist's hotstage: The Microscope, v.36, p. 125-132.

WILSON, M.R. and KYSER, T.K., 1988, Geochemistry of porphyry-hosted Au-Ag deposits in the Little Rocky Mountains, Montana: Econ. Geol., v. 83, p. 1329-1346. Authors at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan, Canada S7N OWO.

The Little Rocky Mountains, Montana, are a result of doming of Archean basement gneisses and Phanerozoic sedimentary rocks produced by the emplacement of quartz monzonite to syenite intrusive complex of early Tertiary age.

The intrusive rocks have whole-rock δ^{18}O values near 8‰, variable initial εNd values from -11 to -19, and initial ^{87}Sr/^{86}Sr ratios from 0.7050 to 0.7061 all of which are compatible with derivation from lower crustal rocks having variable compositions. The Zortman and Landusky mining areas in the Little Rocky Mountains produce Au (and Ag) from fracture systems filled with clay minerals and low concentrations of Au-bearing pyrite within the intrusive rocks. K-Ar ages of illites associated with the Au mineralization are near 60 m.y. and are similar to K-Ar and fission-track ages of the intrusive rocks themselves. The δD and δ^{18}O values of these illites indicate that they, and the Au-bearing pyrite, formed at T near 250°C from meteoric fluids having δ^{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 which host the fracture system, suggesting that Sr, and by inference the Au, most likely was derived from Precambrian basement gneisses.

After the Au was emplaced, later fluids released the Au by oxidizing the pyrite; they then formed kaolinite and hydrothermal fluorite and dolomite. The latter two 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 homogenize at 100° to 200°C and have δ^{18}O values near -10‰ and δD values near -110‰, consistent with those of Tertiary ground waters. The δ^{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)

WIRT, Lauri, 1988, The origin of chloride in ground water in the Stripa granite, Sweden: MS thesis, The Univ. of Arizona, 68 pp.

The origin of elevated levels of chloride in the ground water is problematic at the Stripa Mine in Sweden. Flow occurs through poorly-connected fractures in dense granite and is virtually stagnant. Concentrations of chloride range from 400 to 800 ppm in the ground water, while chloride in the granite is only 160 ppm. Chloride may come from fluid inclusions in the surrounding granite.

To test this hypothesis, samples of Stripa rocks and ground water were measured for stable chlorine isotopes, chloride content, and chlorine-36. Rock samples collected from the 360 m mine level are enriched in chlorine-37, while deeper rock samples are depleted in chlorine-37 with respect to Standard Mean Ocean Chloride (SMOC). The ground-water samples have essentially the same average enrichment and the same average departure from SMOC, but unlike the rock samples, isotopic ratios do not correlate with depth. Because of the similarity in the values of rock and water samples, the chloride could possibly originate from fluid inclusions; however, other sources cannot be excluded. Whether or not the stable chlorine isotopes in the water are in isotopic equilibrium with the surrounding rock tells us something about the distance and direction which the water has traveled. No correlation was found between ratios of stable chlorine isotopes, total chloride, and chlorine-36, indicating that the hydrologic and geologic processes influencing the distribution of each at Stripa are not the same. (Author's abstract)

WITT, W.K., III, 1985, Diffuse (background), and fracture-controlled felspathic alteration in tin-mineralized granites of the Irvinebank-Emuford area, northwest Queensland: PhD dissertation, James Cook Univ. of North Queensland, Australia.

See next item. (E.R.)

WITT, W.K., 1988, Evolution of high-temperature hydrothermal fluids associated with greisenization and feldspathic alteration of a tin-mineralized granite, northeast Queensland: Econ. Geol., v.83, p.310-334. Author at James Cook Univ. of North Queensland, Townsville, Queensland 4811, Australia.

Greisenization, albitization, and K-feldspathization occur as pervasive (background) alteration and fracture-controlled (selvage-style) alteration in the Go Sam granite in the Herberton-Mount Garnet tin fields of northeast Queensland. Optical, SEM, and microthermometric investigations of fluid inclusions, principally from vug-filling minerals [quartz and fluorite] in selvage-style alteration permit interpretation of the nature and evolution of hydrothermal fluids responsible for alteration of the granite.

Saline hydrothermal fluids are dominated by Na-K-Ca-Fe chloride solutions, with Mg, Mn, Zn, Si, Al, Th, Ce, and La relatively minor but important components. Salinities of up to 70 wt.% total dissolved salts have been calculated using the phase volume method.

Indicated Tt of 600° to 650°C for many saline inclusions in vug-filling minerals from feldspathic rocks record minimum T for feldspathic alteration. Inferred T for greisenization are similar and slightly lower (450°-525°C). Tt, and the composition of fluids in saline inclusions, suggest late magmatic to early postmagmatic alteration of the granite by predominantly magmatic fluids.

Inclusions containing relatively dilute fluids of possible meteoric origin have Th 100°-400°C. Salinities as low as 2 eq. wt.% NaCl are indicated and significant CO_3^{-2}, HCO_3^-, or SO_4^{-2} may be present. Associated vapor-rich inclusions indicate that the dilute fluids were probably boiling between 300° and 400°C.

A continuous range of salinities from dilute fluids to saline fluids has been found in the inclusions investigated. Dilution of very saline, high-T fluids could have occurred by separation of dissolved components as the fluid cooled and by mixing with dilute fluids below 400°C.

Data from fluid inclusions in magmatic quartz from the Go Sam granite are similar to those obtained from vug-filling minerals in fracture-controlled alteration occurred contemporaneously and as a result of interaction with the same fluids.

Consistently high T inferred for the formation of all feldspathic rocks and associated greisens do not fit an established Soviet model, which emphasizes falling T, for the origin of comparable rocks. A tentative model which emphasizes high-T evolution of hydrothermal fluids due to changes in chemical parameters (pH, salinity, Na/K, f_{F_2}) and confining P is discussed. (Author's abstract)

Dms, identified by optics and SEM, included $FeCl_2 \cdot 2H_2O$,$CaCl_2 \cdot 6H_2O$, Ca silicate, halite, sylvite, carbonates and/or sulfates, and opaques. Some inclusions consisting of birefringent crystals and little or no liquid may represent an immiscible chloride- or fluoride-rich melt. Some Te values as low as -85°C, but many were -55°C. SEM shows K, Na, Ca, Fe, Mg, Mn, Si, Al, Ti, Cl, S, P, I, Y, Ce, La, Th, Zn, Nb, Zr, Cs, Sn, Cu, and Pb. $ZnCl_2$ may be an important component. No clathrates were observed. The densities of the highly saline inclusion fluids were calculated to be 1.5-1.7 g/cm^3. Th mostly up to 600 and some >700°C, with some evidence of boiling. The various composition inclusions are related, as far as possible, with the various stages of alteration. (E.R.)

WITTRUP, M.B., 1987, The origin of water leaks in Saskatchewan potash mines: MS thesis: Saskatoon, Saskatchewan, Univ. Saskatchewan, 113 pp.

WITTRUP, M.B., KYSER, T.K. and DANYLUK, T., 1987, The use of stable isotopes to determine the source of brines in Saskatchewan potash mines, in Gilboy, C.F. and Vigrass, L.W., eds., Economic Minerals of Saskatchewan: Saskatchewan Geol. Survey, Spec. Pub. No. 8, p. 159-165.

WOLTER, R. and SCHNEIDER, H.J., 1988, Genetic significance of saline relics in carbonate host rocks of Alpine Pb-Zn deposits: Spec. Publ. Soc. Geol. Appl. Min. Deposits 5, 1988, p. 121-131.

Indexed under "Fluid Inclusions." (E.R.)

WOOD, R.H., WHITE, D.E., DAVIS, W.E. and THOMPSON, P.T., 1988, Heat capacity of aqueous $FeCl_2$ from 349 to 597 K: J. Chem. Eng. Data, v. 33, p. 301-306. First author at Dept. Chem. & Biochem., Univ. Delaware, Newark, DE 19716.

A differential, flow, heat-capacity calorimeter has been used to measure the heat capacity of $FeCl_2(aq)$ at molalities from 0.06 to 3.5 mol kg^{-1} and T from 350 to 600 K at a P near 17.9 MPa. The results do not show the large negative values of $C_{p,\phi}$ characteristic of strong electrolytes at high T and low molalities, indicating that $FeCl_2(aq)$ like $NiCl_2(aq)$ is mainly undissociated at high T and molalities above 0.06 $mol \cdot kg^{-1}$. A sharp maximum in $C_{p,\phi}$ versus T may be due to the effects of association equilibria. (Authors' abstract)

WOOD, S.A. and MACCI, A., 1988, The solubility of platinum as bisulfide and hydroxide complexes at 25°C (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 83. Authors at Dept. Geol. Sci., McGill Univ., Montreal, PQ, H3A 2A7, Canada.

Recent theoretical studies suggest chloride complexing cannot account for the aqueous transport of platinum except in highly acidic and oxidizing environments. Bisulfide and hydroxide complexing have been proposed as alternatives. Thus we have undertaken a study of the solubility of Pt in the following solutions at 25°C: Bisulfide solutions from 0 to 0.3 molal at pH = 10-11 and hydroxide solutions at pH from 7 to 14. Ionic strengths were adjusted with either $NaClO_4$ or NaCl to a constant value (1.0 molal) and equilibration periods up to one year were employed. Solubility of Pt in hydroxide solutions attains several ppm and over the range 11-14 appears to be independent of OH^- concentration. In the bisulfide solutions, solubility decreases with bisulfide concentration; however, this is a result of the decrease in Eh with bisulfide concentration. When this effect is taken into account, the solubility of Pt increases with sulfur content. Theoretical thermodynamic calculations suggest that the initial Pt metal should be converted to PtS in these experiments. The surface of the Pt metal shows no apparent change; however, small amounts of a fine black precipitate have been observed on the filters used during the sampling process. Efforts are being centered around identifying this phase. Pt solubilities on the order of several tens to hundreds of ppb have been measured in bisulfide solutions. The pH range of these experiments is presently being extended towards more geologically reasonable values. (Authors' abstract)

WOOD, S.A. and VLASSOPOULOS, D., 1988, The hydrothermal solubility of tungsten oxides at 500°C and 1 kbar in HCl, NaCl, NaOH and pure water solutions (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 83. Authors at Dept. Geol. Sci., McGill Univ., Montreal, PQ, H3A 2A7, Canada.

Solubilities of WO_2, WO_3 and WO_2/WO_3 mixtures in HCl, NaOH and NaCl solutions, as well as in doubly distilled water, were determined at 500°C and 1 kbar using cold seal hydrothermal apparatus. Runs were contained in Au capsules and an argon P medium was employed. The WO_3/WO_2 mixtures were intended for use as an oxygen buffer. Typical run times were on the order of one week.

The solubility of unbuffered WO_3 in distilled water was determined to be 492 ± 100 ppm at 500°C compared to 5.3 ppm at 25°C and approximately 370 ppm at 600°C and 2 kbar (Eugster and Wilson, 1985). The solubility of WO_3 in 0.5 to 5 m HCl solutions was the same as in pure water and the quench pH indicated no consumption of H^+ during dissolution . The average solubility of the WO_3/WO_2 mixtures in pure water was 900 ppm and that of WO_2 alone was 2380 ppm. Thus, W speciation would appear to be dependent on oxygen fugacity, probably due to a change in speciation from a W(VI) to a W(V) species. In the runs involving WO_2, the final solid product was always the mixed oxide, $W_{18}O_{49}$, and the solutions were blue in color on quench. The solutions in experiments involving WO_3 only were colorless. The solubility of WO_3 increased to approximately 7.2 wt % in 1 molal NaOH, suggesting either Na-tungstate ion-pairing or a pH effect. The solutions containing NaOH were also a deep blue in color on quench and the quench pH was near neutral, suggesting consumption of OH^- ions. (Authors' abstract)

WOOD, Theresa and BARKER, Charles, 1988, Cathodoluminescence microscopy: Present and future applications (abst.): The Microscope, v. 36, p. 256-257.

WOODRUFF, L.G. and SHANKS, W.C., III, 1988, Sulfur isotope study of chimney minerals and vent fluids from 21°N, East Pacific Rise: Hydrothermal sulfur sources and disequilibrium sulfate reduction: J. of Geophy. Res., v.93, n.B5, p.4562-4572.

WOOLLEY, A.R., 1987, Alkaline rocks and carbonatites of the world. Part I. North and South America: Univ. Texas Press, 222 pp.

WOPENKA, Brigitte and PASTERIS, J.D., 1988, "Graphites" in geological samples: Raman spectroscopic misfits?, in D.E. Newbury, ed., Microbeam Analysis - 1988: San Francisco Press, Inc., San Francisco, CA, p. 196-200.

Raman spectroscopic analysis of geological carbonaceous materials reveals a wide range in structural and compositional deviations from well crystallized pure carbon graphite. (From the authors' Conclusions by E.R.)

WOTRUBA, P.R., BENSON, R.G. and SCHMIDT, K.W., 1988, Geology of the Fortitude gold-silver skarn deposit Copper Canyon, Lander County, Nevada, in Proc. 1987 Symp. Bulk mineable precious metal deposits of the western United States, R.W. Schafer et al., eds.: Geol. Soc. Nevada, p. 159-171. Authors at Battle Mountain Gold Co., Battle Mountain, NV.

The Fortitude Au-Ag deposit is related to a "wallrock" Cu porphyry system developed within Middle Pennsylvanian to Permian Antler Sequence carbonate and coarse clastic rocks adjacent to an altered granodiorite intrusive stock at Copper Canyon. The Fortitude deposit and other ore bodies at Copper Canyon lie within the northwest-trending Battle Mountain-Eureka mineral belt of north-central Nevada. Au-Ag ores of the Fortitude deposit occur with disseminated and massive sulfide replacement mineralization of skarn-like or calc-silicate limy horizons of the Antler Sequence sedimentary rocks. A major north-trending, steeply westward dipping normal fault was an important conduit for hydrothermal fluids responsible for metallization in the Fortitude area. Au-Ag mineralization is best developed near a marble alteration front where retrograde chloritization and destruction of prograde calc-silicate mineral phases is most prevalent. Fluid inclusion studies indicate a wide variation in fluid chemistry during several hydrosilicate stages that ranged from 500°C to 250°C. Rock chip geochemistry did not adequately define the existence of the Fortitude deposit in the highly-mineralized Copper Canyon area. Airborne and ground magnetometer surveys delineated the Fortitude deposit and were instrumental in the discovery process. (Authors' abstract)

WRIGHT, J.H. and KWAK, T.A.P., 1988, Endogreisen, brecciation and fluid activity at the Mount Bischoff Sn-deposit, northwest Tasmania, Australia: J. Metamorphic Geol., v. 6, p. 629-650. First author at Mt. Kersen Mining, 44 St. George's Terrace, Perth 6000, Western Australia.

Endogreisens which replace K-feldspar-quartz dikes in a Devonian (360 Ma) tin deposit at Mt Bischoff, northwest Tasmania, formed from the interaction of unusual solutions, probably derived from an underlying leucogranite pluton, porphyry dikes and limited quantities of local dolomitic country rock components. The T during greisenization ranged from 180 to 414°C, based on fluid inclusions in topaz, quartz, fluorite, sellaite and cassiterite. The main greisen-forming event occurred at 360 ± 20°C. The fluids boiled intermittently. Their salinities ranged from 31.5 to 38.9 wt% total dissolved salts, consisting of Ca-K-Na-Fe-Cl ± hydrocarbon species. Fluid inclusion data indicate that only 0.5-1.5 km of cover were present above this deposit at the time of formation. The Mt Bischoff greisen system is possibly part of a 'porphyry tin' style deposit formed at near-surface conditions (0.5-1.0 km). (From the authors' abstract by H.E.B.)

XAVIER, R.P., 1988, Characterization and evolution of ore-forming fluids at Fazenda Brasileiro gold mine, Rio Itapicuru greenstone belt, BA: Revista Brasil. de Geoci., v. 18, no. 4, p. 483-493. Author at Dept. Geol., Univ. Southampton, Southampton SO9 5NH, UK.

Fluid inclusion studies by microthermometry and Raman spectroscopy carried out on the main hosts of the Au mineralizations at Fazenda Brasileiro mine, southern part of Rio Itapicuru greenstone belt define the mineralizing fluids as relatively dense (0.85-0.95 g/cm^3) and hot (> 400°C) solutions composed essentially of CO_2 (89.7-85.3 mole%) and minor amounts of CH_4 and N_2, which gradually evolved to more aqueous fluids (40 to 62.5 moles% H_2O) of low salinity (< 10 eq. wt% NaCl) at lower T (250-300°C). The isochores of the carbonic H_2O-CO_2 fluids and the T of Th(total) combined with geothermometric data on the paragenesis, point to at least two periods of Au deposition: 1. 380-419°C and 2.2-3.2 kb in the quartzofeldspathic and arsenopyrite-pyrite quartz veins and 2. 270-300°C and 1.2-1.4 kb in the massive quartz vein. Based on experimental work on the solubility of Au complexes, chemical characteristics of mineralizing fluids, ore paragenesis and Au/Ag ratio, it was possible to speculate that the transport of Au occurred mainly by reducing (high $\Sigma H_2S/\Sigma SO_4$), slightly neutral to alkaline solutions, as thio-complexes such as $Au(HS)_2$, $HAu\ (HS)_2^\circ$ or $Au(HS)_2S^{-2}$. In the earliest stage of mineralization conditions of Au deposition were probably attained due to fluid/rock reactions which led to a decrease in the activity of S^{-2} by precipitating sulphides (arsenopyrite, pyrite, pyrrhotite, etc). The predominance of the H_2O regime over the CO_2 regime in the latest stage might have been the cause of CO_2 dilution, decrease in pH and oxidation and, as a consequence, the precipitation of Au. The fluid inclusion data also suggest a metamorphic origin for the mineralizing fluids, most likely through the devolatilization of the basal sequences of the volcano-sedimentary pile. The devolatilization process would be able to produce low salinity, H_2O-CO_2 fluids which would later migrate through favorable structural sites and deposit their metal content. (Author's abstract)

See also Xavier, 1987, Fluid Inclusion Research, v. 20, p. 411. (E.R.)

XIA, Linqi, 1988, Phase equilibria in fluid inclusions: Bull. Xi'an Inst. Geol. & Min. Resources, The Chinese Acad. Geol. Sci., 1988, no. 21, p. 75-106 (in Chinese; English abstract).

Discusses the physical chemistry necessary to adequately interpret fluid inclusion heating and freezing data. (H.E.B.)

XIA, Linqi, 1988b, On study of chemical compositions of magmatic inclusions: Acta Petrol. & Mineral., v. 7, no. 1, p. 1-10 (in Chinese; English abstract). Author at Xian Inst. Geol. & Min. Resources, GAGS.

Magmatic inclusions can directly provide valuable information on the chemical composition variation of crystallization evolution of natural magma. In order to obtain correct and reliable chemical composition data of magmatic inclusions and to be able to explain and deduce them reasonably, we have to pay great attention to following problems:

1) The chemical compositions of non-evolved magmatic inclusions may represent their initial compositions. The chemical compositions of glass phases in evolved magmatic inclusions cannot represent their initial compositions. We have to analyze the quenched inclusions after homogenization in order to obtain the initial chemical composition of this type of evolved inclusions.

2) The homogenization thermometry study of magmatic inclusions has to follow strictly the thermometrical rule[sic].

3) The author's experiments reveal that the influence of "boundary layer effect" upon the chemical composition of magmatic inclusion is insignificant.

4) The chemical composition of magmatic inclusions represents only the composition of ambient magma during crystallization growth of their host minerals. The detailed study of magmatic inclusions in various minerals of magmatic rocks can help us to reconstruct more completely the evolution history of magma.

5) The more mature methods of study on volatile materials trapped in magmatic inclusions [include] combining Raman microprobe spectrometry, microprobe analysis and microthermometry. (Author's abstract)

XIE, Wenan, 1988, Fluid inclusion studies of minerals from two types Pb-Zn deposit in southern Hunan: Geol. & Prospecting, v. 24, no. 6, p. 9-16 (in Chinese; English abstract). Author at Hunan Inst. Geology.

Based upon the results of P fluid inclusion, Th, freezing salinity, gas-liquid chemical composition, pH, Eh and electrical conductivity, some important problems concerning mineralizing fluid features, minerogenetic physical and chemical conditions and origins of the two different types Pb-Zn deposits in southern Hunan are discussed. (Author's abstract)

XIE, Yihan, ZHAO, Rui, LI, Ruomei and WANG, Yingian, 1988, Physical-chemical conditions and material sources for mineralization of the Yinyan porphyry tin deposit: Min. Deposits, v. 7, no. 3, p. 42-49 (in Chinese; English abstract). Authors at Inst. Geol., Acad. Sinica, Beijing.

Based on fluid inclusion studies, this paper discusses tentatively the physical-chemical conditions and material sources for mineralization of the Yinyan porphyry Sn deposit, with the main understanding summarized as follows:

1. The minerals in the porphyry Sn ore contain lots of high-salinity fluid inclusions and CO_2-rich inclusions. It has been determined that the

ore-forming fluids had salinity as high as 40-64 wt% NaCl, T from 300°C to 460°C, P ~100 bar, fO_2 10^{-25} bar, fCO_2 $10^{1.1}$ bar, and Eh ~0.8, so porphyry Sn-mineralization must have taken place under the condition of weak reduction and boiling of ore-forming fluids caused by deceasing P.

2. Minerals in the veinlike Sn ore contain only a few liquid inclusions. The ore-forming fluids had low salinity of 2-7 wt% NaCl, T from 260°C to 320°C, P some 300 bar, fO_2 10^{-21}, fCO_2 $10^{0.27}$ bar, and Eh ~0.8. It is therefore considered that this sort of Sn ore must have formed during a decrease in T and salinity of the ore-forming fluids.

3. The H and O isotope data of the inclusions suggest that the metallogenic fluids forming the porphyry Sn deposit mostly came from the magma, and that during the formation of veinlike ore, magmatic water was mixed with rain. (Authors' abstract)

XU, Butai, XIA, Anning, ZHENG, Shuhui and CHEN, Chengye, 1988, Characteristics and sources of ore-forming fluids in the Zhilingtou gold-silver deposit studied by stable isotope method: Min. Deposits, v. 7, no. 4, p. 27-32 (in Chinese; English abstract). First author at Zhejiang Inst. Geol. Sci., Hangzhou, Zhejiang.

The Zhilingtou Au-Ag deposit in Zhejiang province occurs in metamorphic rocks of Proterozoic Chencai Group and Mesozoic volcanic rocks. A study of stable isotopes in the deposit shows that vein quartzes and their inclusions of two mineralization epochs [each] have their respective characteristics of stable isotopic composition. In the early epoch, the quartzes have $\delta^{18}O$ values of +8.2 to +9.9‰, hydrothermal water $\delta^{18}O$ values of +1.0 to +3.1‰ (obtained from isotope fractionation equation of quartz-water), and inclusion δD values and $\delta^{13}C$ values of -59 to -61‰ and -0.12‰ respectively, while in the late epoch, the quartzes have $\delta^{18}O$ values of +5.5 to +8.3‰, hydrothermal water $\delta^{18}O$ values of -2.1 to -3.9‰, and inclusion δD values and $\delta^{13}C$ values -58 to -73‰ and -5.4 to -5.6‰ respectively.

On the basis of the above, combined with geologic and petrological-mineralogical data, the authors hold that the ore-forming fluids of the early mineralization epoch and of the late epoch came respectively from metamorphic water of Proterozoic Choncai Group and mixed circulating water of Mesozoic volcanic-magmatic water and ancient meteoric water. It is therefore considered that the Zhilingtou Au-Ag ore deposit is a composite one formed through superimposition of ore-forming fluids from various sources. (Authors' abstract)

XU, Guofeng, 1988, Source of mineralized material of transmissive hot brine-supergene reformation type gold deposit from Jinchangzi in Ningxia, China: Earth Sci., v. 13, no. 2, p. 147-153 (in Chinese; English abstract). Author at China Univ. of Geosci.

The results of investigation of stable isotope S and minor elements (Au) of rocks and the geological characteristics indicate that the source of mineralized material of Au deposit from Jinchangzi in Ningxia comes from the upper crust, and Au, Ag, Pb, Cu, etc. and S, Se, As, Cl, F, etc. [come from] Carboniferous and Devonian sedimentary rocks. The ore-forming fluid is a mixed solution of atmospheric water and sedimentary stratal water. Au mineralization is related to metallogenesis of transmissive hot brine geothermal fluids and of supergene weathering. (Author's abstract)

YAMADA, Ryouichi, NISHITANI, Yoshioki, TANIMURA, Shoujiro and KONISHI, Naotoshi, 1988, Recent development and geologic characteristics of the Nurukawa kuroko deposit: Mining Geol., v. 38, no. 4, p. 309-322 (in Japanese; English abstract). First author at Dowa Mining Co., Ltd., Hanaoka-machi, Odate, Akita, Japan. Continued next page.

The Nurukawa kuroko deposit was discovered in 1984 and commenced its production in 1987. Current monthly production is 5,000 tons of ore grading 6.8 g/t Au, 123 g/t Ag, 0.74% Cu, 3.86% Pb, and 7.92% Zn. The deposit consists of five discrete ore bodies; Nos. 5 and 3 ore bodies are [being mined] and the rest are [under] exploration stage. Among them, No. 5 ore body is the largest in size and highest in ore grade. It is characterized by Au and Ag rich black ore (massive sulfide) and Au-bearing siliceous ore which develops in footwall tuff breccias. The latter ore is subdivided into two types, namely, stratiform and stockwork types, on the basis of its mode of occurrence and distribution. The statiform type siliceous ore is composed of fragments of Au-bearing network ore of quartz-chalcopyrite-pyrite and interstitial siliceous matrix rich in Pb and Zn. On the contrary, the stockwork type siliceous ore is rich in chalcopyrite and pyrite and is overprinted by Pb and Zn mineralization.

No. 3 ore body consists of bedded clayey black ore which is considered to have replaced tuff breccia, fine-grained massive black ore contaminated with muddy material, and underlying gypsum ore. No. 2 ore body is composed of massive sulfide ore which is zoned vertically into black and yellow ores, and ore composed of fragmented and transported massive sulfides. Those are underlain by gypsum and siliceous ores.

The wall-rock alteration zoning around the Nurukawa deposit is: sericite-chlorite, mixed-layer clay, montmorillonite, and zeolite zones, in ascending order. Kaolinite and kaolinite-montmorillonite mixed-layer clay mineral are observed above the black ore of the Nos. 3 and 5 ore bodies. The mineralization age determined by K-Ar method on sericite samples has a range between 10.7 and 12.5 Ma with an average of 11.7 Ma. Th of fluid inclusions in quartz cluster around 265-281°C. It is suggested that no boiling had occurred during the formation of the deposit. The $\delta^{34}S$ data on mineral separates and bulk sulfide ores range from +4.8 to +6.8‰ except one sample.

All of these geochemical data coincide with "ordinary" values of the kuroko deposits of the Hokuroku area. Therefore, it is not easy to explain the reason why the Nurukawa deposit has extremely high Au content compared to other kuroko deposits. However, positive relationship between salinity and Th of the fluid inclusions and geologic reconstruction of the area both suggest that the formation of the deposit appears to be happened near shore where ore-forming solution was diluted by meteoric water. This mixing might effectively cause the precipitation of Au. (Authors' abstract)

YAMAMOTO, K., 1988, Chemical compositions and fluid inclusions of clinopyroxene and garnet from the Senno deposit, the Nakatatsu mine (abst.): Mining Geol., v. 38, no. 1, p. 72-73 (in Japanese; translation courtesy S. Takenouchi).

Formation of skarn of the Nakatatsu Pb-Zn skarn deposits was studied from the viewpoint of fluid inclusion and chemical composition of minerals. Th and salinity of fluid inclusions were 440°-520°C and ~50 wt.% for early short prismatic clinopyroxene, 340°-410°C and ~8 wt.% for later long prismatic clinopyroxene, and 350°-370°C for later garnet, respectively. It is concluded that the early wollastonite-bustamite and calcite-clinopyroxene skarns were formed by high-T and high-salinity hydrothermal solutions followed by the formation of clinopyroxene skarn at T and salinity conditions lower than the former, and that garnet skarn was formed replacing the early skarns according to the change of fO_2. (Author's abstract)

YANG, M.M., CRERAR, D.A. and IRISH, D.E., 1988, Raman spectroscopic studies of hydrothermal solutions (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 84. First author at Dept. Geol.

& Geophys. Sci., Princeton Univ., Princeton, NJ 08544, USA.

Although recent advances have been made in the study of hot aqueous solutions, there is still very little information about the stoichiometries, structures and stabilities of metal complexes at high T and P. Raman spectroscopy is ideally suited to probe and study electrolyte solutions at the molecular level. We have designed a Raman cell operable up to 300°C and 18 MPa to facilitate such measurements. In order to obtain quantitative thermodynamic information from Raman spectroscopic measurements, a chemically inert internal standard must be used. Perchlorate is commonly used for this purpose at low T, but it is unstable (explosive) and reactive at high T. We introduce and have studied the spectra of a new internal standard (trifluoromethanesulfonic acid) up to 300°C. The use of this compound as high T internal standard enabled stepwise stability constants of zinc-bromo complexes to be determined. The species $ZnBr_n^{2-n}$ ($n = 1,2,3,4$) were observed. Although bromide is not an important ligand in geologic systems, its chemical similarity to chloride can provide insights into the study of zinc-chloro species which do not have very informative Raman spectra. We have also completed the first high T spectroscopic measurements of lead and zinc acetate solutions. The species $ZnAc_n^{2-n}$ and $PbAc_n^{2-n}$ ($n = 1,2,3$) were observed. Not only do these studies verify the stability of lead and zinc complexes up to 250°C but they also show that the type of complex formed is a function of pH, metal-ligand ratio and T, thus having important implications for deposition and zoning of Pb-Zn sulfide deposits. (Authors' abstract)

YANG, Yueqing, NI, Yunxiang, GUO, Yongquan, QIU, Nianming, CHEN, Chenghu, CAI, Chaofa, ZHANG, Yaping, LIU, Jiabin and CHEN, Yuexian, 1988, Petrogenetic and metallogenetic characteristics of the Xikeng granitic pegmatites, Fujian Province: Geochemistry (Chinese), v. 7, p. 120-135. First author at Inst. Min. Deposits, Chinese Acad. Geol. Sci., PRC.

The pegmatites can be grouped into four types: muscovite-orthoclase-albite pegmatite (I), muscovite-albite-orthoclase pegmatite (II), muscovite-orthoclase-albite pegmatite (III), and muscovite-albite-spodumene pegmatite (IV). Owing to strong metasomatism and multi-stage emplacement of pegmatitic melt-solution, the sequence of interior assemblage zones in the pegmatites does not always represent the sequence of original crystallization. The mineral composition of the pegmatites is extremely complicated. 81 kinds of minerals have so far been found. From type I to type IV, the mineral assemblage tend to get increasingly complex, together with the synchronous intensification of rare-metal and Sn mineralizations. Most of the type-IV pegmatites are of economic value. The features of fluid inclusions in the minerals are significantly different not only in different types of pegmatite, but also in different parts of a single pegmatite vein. The $\delta^{18}O$ values of migmatitic granite and pegmatites are comparatively low (9.3-10.4‰), and those of rock-forming fluids are higher than 9.5‰.

Isotopic ages of the pegmatites range from 235 to 328 Ma with initial $^{87}Sr/^{86}Sr$ ratios being 0.715-0.746. According to the temporal and spatial relationships between the pegmatites and the migmatitic granite, combined with the features of the pegmatites themselves, it can be concluded that the Xikeng pegmatites are the products of differentiation closely related to the migmatitic granite. (From the authors' abstract by H.E.B.)

YARDLEY, B.W.D. and BOTTRELL, S.H., 1988, Immiscible fluids in metamorphism: Implications of two-phase flow for reaction history: Geology, v. 16, p. 199-202. Authors at Dept. Earth Sci., Univ. Leeds, Leeds LS2 9JT, England.

Fluid immiscibility between a CO_2-rich fluid and brine has been described from several medium- to high-grade marbles and calc-silicates. Here we also report evidence for CH_4-H_2O immiscibility in low-grade metamorphic rocks from Wales and suggest that the flow of such immiscible fluids may be comparable to that of water-oil or water-gas mixtures in petroleum reservoirs. This analogy implies that where one fluid is being produced by reaction it will flow out of the rock while the other remains immobile, except insofar as it is soluble in the more abundant fluid phase. Hence, extensive reaction may take place in the presence of coexisting immiscible fluids, each having high activities. It is proposed that this type of flow behavior not only accounts for the development of salt-saturated fluids in marbles but also may be responsible for the elimination of carbonate and extensive loss of graphite from pelites in the lower part of the greenschist facies. (Authors' abstract)

YASUHIRO, Shibue, 1988, Importance of tungstate species for the transport of tungsten in hydrothermal solution: Case studies on major Japanese tungsten deposits (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 84. Author at Geosci. Inst., Hyogo Univ. of Teacher Education, Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

Thermodynamic calculations on the stability relations among various tungsten species are performed in order to elucidate the possible form of tungsten during the transportation in hydrothermal solution, using the knowledge of fluoride and chloride concentrations.

P and T conditions for the formation of major Japanese tungsten deposits at Kaneuchi, Ohtani, Takatori, Fujigatani, Kiwada, and Kuga are obtained to be from 1 to 2 kbars and from 300° to 600°C, respectively. Based on the fluorine contents in micas and topaz and the fluid inclusion data, it is calculated that the logarithmic values of HF/H_2O and HCl/H_2O fugacity ratios in the hydrothermal solutions for the studied deposits range from -3.15 to -5.91 and are less than -3.33, respectively. Oxygen fugacities are assumed to be those defined by the C-CO-CO_2 buffer as the most reducing condition encountered.

Based on the P, T, $f(O_2)$, $f(HF)/f(H_2O)$ conditions evaluated for the studied deposits, thermodynamic calculations are performed to compare the stabilities of halogen-bearing species with those of tungstates. Calculated results show that H_2WO_4 may be a predominant species in the natural hydrothermal solutions responsible for the formation of major Japanese tungsten deposits. (Author's abstract)

YOUNG, D.P., 1988, The history of deformation and fluid phenomena in the top of the Wilderness suite, Santa Catalina mountains, Pima county, Arizona: MS thesis, The University of Arizona.

Equigranular Wilderness granite and pegmatitic Lemmon Rock leucogranite, leucocratic members of the Eocene Wilderness suite, are peraluminous granitic units containing almadine-spessartine garnet and two micas. Lemmon Rock leucogranite is slightly more differentiated than Wilderness granite and intrudes the contact of the Wilderness granite with country rocks.

Wilderness suite rocks intruded highly deformed country rock producing an extensive amphibolite-grade metamorphic aureole that appears to anneal pre-existing deformational fabrics. Post-emplacement deformation, intensely developed in Wilderness suite rocks south and west of the study area, is weakly and irregularly developed Wilderness suite rocks of the study area.

Fluid inclusions in Wilderness suite rocks contain early aqueous fluids of possible magmatic origin, mixed H_2O-CO_2 fluids of possible metamorphic origin and late aqueous fluids of meteoric origin. CO_2 contents of mixed fluids decreased with time. Mixed H_2O-CO_2 fluid inclusions occur in primary igneous quartz and in early, remobilized quartz fracture fillings but are destroyed in extensively deformed, recrystallized quartz. Fluid inclusion geobarometry suggests that the Wilderness suite was emplaced at a depth of about 13 km. (Author's abstract)

YU, Cimei, 1987, The studies of fluid inclusions and the discussions of the sources of ore-forming materials in porphyry type lead-zinc deposits in China (abst.): Abstracts of Second Nat'l. Mtg. on Experimental Studies of the Fluid Inclusions in Minerals and the Genesis of Rocks and Minerals, Oct. 1987, p. 200-201 (in Chinese; translation by H.-Z. Lu). Author at Changsha Inst. Geotec-tonics, Acad. Sinica.

Porphyry-type Pb-Zn deposits have been found in Shandong, Jiangxi, Hunan, Yunan and elsewhere in China. By summing up research work, the author finds that fluid inclusions are abundant in quantity and types in the porphyry-type deposits in China and suggests that the ore-forming fluids are weakly alkaline salty solutions which are rich in volatile components and high to intermediate T and saline. In terms of stable isotopes, the inclusion water is magmatic, the sulfur is near to meteoric sulfur, and the Pb of the ores is in accord with Pb of the porphyry host, which is evidence that Pb, Zn, S are mainly from magmatic differentiation, in the porphyry type Pb-Zn deposits in Xixia area Shandong Province, Beiya area Yunnan Province and elsewhere. In some deposits, it is also possible that ore-forming elements were remobilized and concentrated from metal elements that were dispersed in the country rocks in the process of magmatic intrusion. In the minerogenic processes, the postmagmatic hydrothermal solutions have major effects but a little meteoric water was involved. These Pb-Zn deposits are in the large fracture zones of the Diwa tectonic region. (Author's abstract)

YU, Cimei, 1988a Study on fluid inclusion in the Xiyupi Pb-deposit and its petrogenetic-minerogenetic mechanism: Geotectonica & Metallog., v. 12, no. 4, p. 317-326 (in Chinese; English abstract). Author at Changsha Inst. Geotec., Acad. Sinica.

This paper applies fluid inclusion research to studies of the physical-chemical characteristics of the mineralized fluid of the Xiyupi Pb deposit and the genesis and petrogenetic-minerogenetic mechanism of the deposit. The author gains systematic data or the petrogenetic-minerogenetic conditions of the deposit through field investigations and laboratory analysis (including fluid inclusions, Pb, S isotopic and rock-mineral analyses). The results suggest that the ore-forming material in the deposit was derived mainly from the Xiyupi migmatite in the crystalline basement. Though the deposit experienced complex geological evolution, the present mineral fluid inclusions still keep the characteristics of petrogenetic-minerogenetic fluid of sedimentation-metamorphism-migmatization. Therefore, the Xiyupi Pb deposit is a Pb-rich ore deposit re-enriched by hydrothermal processes of sedimentation-metamorphism-migmatization. (Author's abstract)

YU, Cimei, 1988b The study of chemical compositions of ore-forming fluids in lead-zinc deposits of various types in China (abst.): Abstracts of Third Nat'l. Symp. on Minerals, Rocks and Geochemics, Oct. 1988, p. 218 (in Chinese; translation by H.-Z. Lu). Author at Changsha Inst. Geotectonics, Acad. Sinica.

Analysis of results of the chemical composition of water in [fluid] inclusions in various types Pb-Zn deposits in China shows that the gases vary with the genetic types of the deposits, and even within some genetic deposits, because of differences in geological environment. The sources of materials in the ore fluids vary with the deposit genesis. Thus in porphyry type and continental volcanic rock type deposits CO_2 comes mainly from magma and in metasediment type deposits it results from the action of high T metamorphic hydrothermal solutions on carbonaceous materials in country rocks. Because mudstone type deposits have more strongly reduced conditions during metallization, CH_4 is highest in these deposits. In most deposits the atomic ratios Ca/Mg in ore fluids are >1. The atomic ratios Na/K, Na/Ca and Na/Mg in ore fluids of Pb-Zn deposits in old strata are also >1, which evidences that ore-forming fluids include very high Na and always form rich Pb ore bodies. In porphyry type deposits, F^-, Cl^-, SO_4^{2-} of ore-bearing hydrothermal solutions which come from subvolcanic hydrothermal solutions are all very high. And in those deposits which are related to deep source hot-brines, Cl^-, SO_4^{2-} are also high. The determination of pH values evidences that the ore-forming fluids are alkaline in most deposits, a few pH values even reaching 9.25, and weakly alkaline to intermediate in a few deposits. The changes of acid-alkaline specifics of ore-forming fluids are markedly related to minerogenic environments and show the changes of materials in the processes of remobilization, migration and concentration. The author suggests that the ore-forming fluids of Pb-Zn deposits of various types in China are alkaline to intermediate fluids which are rich in CO_2 and CH_4 and with atomic ratio Ca/Mg >1 and Cl/F generally very high. They are mainly Cl^- and SO_4^{2-} fluids. The host rocks are more or less carbonate formations (or carbonaceous rocks). (Author's abstract)

YU, D.L., 1988, A study of the fluid inclusion of Mobin gold deposit, Hunan (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 503-505. Author at Guizhou Inst. of Tech., Geol. Dept., Guiyang, Guizhou, PRC.

Most inclusions are liquid-rich, plus a few vapor-rich and liquid-only types. Th 120-220 (mainly 160-180°C). Salinities are 1-5 wt% NaCl eq., mostly 2-3%. Na>K and Ca>Mg; Li is lower. (E.R.)

YU, Yunmei and WANG, Yurong, 1988, An experimental study of biotite in Na-, F-, and Li-rich pneumatolyto-hydrothermal solutions: Geochemistry (Chinese J.), v. 7, no. 1, p. 76-87.

ZAW, Khin, 1987, A preliminary fluid inclusion study on the Tennant Creek deposits, in "Geology and geochemistry of gold-copper iron oxide systems: Tennant Creek and Starra Districts Vol. II, Workshop Manual No. 1, Tennant Creek, July 1987, Univ. Tasmania, p. 200-212.

Fluid inclusions in quartz and carbonate samples from the Tennant Creek Au field were studied, yielding the following points: (1) the Th give more than 350°C for quartz in the Au zone of the Juno deposit. (2) The fluids were considerably saline with 18.00 to 37.6 NaCl eq. wt %. (3) The fluids were also enriched in CO_2 with ~10.56 wt %. (4) The tentative P estimate from fluid inclusions salinity and Th gave >375 bars which = 975 m. (5) The ore-forming environment coexisted with H_2O-CO_2-NaCl fluids but the precipitation mechanism of Au cannot be assessed and the experimental data on Au behavior in the H_2O-CO_2-NaCl system is also still not known. (6) No unambiguous fluid inclusion evidence of boiling of the ore fluid was found but fluid immiscibility in the H_2O-CO_2-NaCl was noted by petrographic investigation of the fluid inclusions in the quartz samples associated with high Au grades. (7) Due to the control of fluid pH through mineral equilibria, according to Ellis (1970) high salinity implies relatively low pH regardless of gas content. At Tennant Creek the presence of CO_2 adds to support the low pH conditions and the fluid inclusion evidence thus strongly suggest that the Tennant Creek ore fluid was under a low pH environment. (8) The presence of CO_2-rich and salt-rich inclusions in the same healed fracture and same sample also indicate that the ore-forming environment was under relatively high P and high T according to the CO_2 solubility data in H_2O-NaCl system of Takenouchi and Kennedy (1965). (From the author's text by E.R.)

ZAW, Than and TAKENOUCHI, S., 1988, Fluid inclusion study of the Shiroji ore from the Kamioka ore deposit, Gifu Prefecture (abst.): Mining Geol., v. 38, no. 1, p. 68-69 (in Japanese; translation courtesy S. Takenouchi).

Th and gas composition of fluid inclusions in quartz, sphalerite, garnet, clinopyroxene and calcite were determined in order to know the genetic conditions of skarn, disseminated ore, Shiroji ore, Ag ore and later calcite vein. Th is as follows: garnet in skarn (280°-340°C) and quartz in skarn (270°-330°C); quartz in disseminated ore (220°-290°C); quartz in Shiroji ore (140°-170°C); quartz in Ag ore (130°-170°C); calcite vein (110°-170°C). Gas analysis was carried out with the decrepitation method in vacuum and gas chromatography. CO_2 mole fraction among the major gases (CO_2, CH_4 and N_2) of skarn was the lowest (0.4-0.7) and it increases toward the later stages. Th decreases in the order of skarn, disseminated ore, Shiroji ore, Ag ore and calcite vein, but CO_2 mole fraction increases according to this sequence (for skarn 0.4-0.7), disseminated ore 0.7, Shiroji ore 0.6-0.8, Ag ore 0.6-0.9 and calcite vein nearly 1. (Authors' abstract)

ZENGER, D.H. and DUNHAM, J.B., 1988, Dolomitization of Siluro-Devonian limestones in a deep core (5,350 m), southeastern New Mexico: Sedim. & Geochem. of Dolostones, SEPM Spec. Pub. No. 43, p. 161-173. First author at Geol. Dept., Pomona College, Claremont, CA 91711-6339.

Obliterative replacement dolomite in the upper part [shows] average Th (P uncorrected) of fluid inclusions for selected groups of dolomite crystals suggesting a general direct relation of crystal size and range from 130°C for fine centimicron-size crystals to 193°C for saddle dolomite.

A sequence containing dolomitized tidal flat features and intimate associations of calcite and dolomite intraclasts suggests early dolomitization. Some deep burial dolomitization is indicated by dolomite growth along stylolites; more pervasive late dolomitization is suggested by broader bands of dolomite, whose geometry suggests stylolite control. Coarse crystallinity, xenotopic fabric, relatively depleted $\delta^{18}O$ values for all dolomite types, trace-element content, and limited fluid inclusion data strongly suggest the influence of hot and deep subsurface solutions, but it is unclear whether the dolomite resulted from mesogenetic replacement, early dolomitization followed by neomorphism in the burial environment, or some combination of those two "end-member"models. (From the authors' abstract by E.R.)

ZHANG, Cheng and JIN, Jingfu, 1988, A mathematical simulation of the movement of ore-bearing hydrothermal fluids in the Hongquan uranium ore deposit: Mineral Deposits, v. 7, no. 4, p. 83-89 (in Chinese; English abstract). First author at Xian Inst. Geol. & Min. Resources, Xian, Shangxi.

The metallization of Hercynian groundwater ore-bearing hydrothermal fluids played an important role in the further concentration of ore bodies in the Hongquan U ore deposit. The investigation into the migration direction of Hercynian ore-bearing hydrothermal fluids and the favorable positions for U metallization is therefore of great significance in search for rich ore bodies.

Studies show that groundwater was heated during its ascent as a result of the effect of geothermal gradient and extracted U from the giant alaskite, forming ore-bearing hydrothermal fluids. From the relationship between internal P (p) of fluids in porous media and stress of the media (σ), i.e., $p = c\sigma$, it is known that the movement of ore-bearing fluids are controlled by structural stress. The finite element method is hence adopted to determine the distribution pattern of structural stress field and, on such a basis, to investigate the migration direction of the ore-bearing hydrothermal fluids and the favorable positions for U precipitation.

The azimuths of various stress axes (Fig. 4) are obtained from the polar equidensity diagram (Fig. 3). It is seen that the maximum principal stress is in approximately horizontal SN direction in this area. The contour map of maximum principal stress (Fig. 6) calculated for network diagram of structure-finite elements (Fig. 5) shows that the ore-bearing hydrothermal fluids moved from high stress area to low stress are under the action of structural stress, and were concentrated to form ore deposits in contact zones between the giant alaskite and metamorphic schist which were geologically and physicochemically favorable for ore deposition. It is therefore concluded that these contact zones are promising places for ore-prospecting. (Authors' abstract)

ZHANG, Dehui, 1988, On the liquid fractionation origin of wolframite quartz veins: Geol. & Prospecting, v. 24, no. 7, p. 15-20 (in Chinese; English abstract). Author at China Univ. of Geosci., Wuhan.

The author holds that during the formation of wolframite quartz veins liquid fractionation is widespread and of important metallogenic significance. The magma, after emplacement, separates into dry magma and transitional ore-forming fluids. The latter, after injection into fractures, fractionates into hydrothermal fluid and metallogenetic melt mass which separates once again to form the aggregate of wolframite and other minerals. The cause accounting for the liquid fractionation is also discussed in this paper. (Author's abstract)

ZHANG, Ligang, 1988a A study on the stable isotopes of some W-Sn deposits in southern China (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 85. Author at Yichang Inst. of Geol. & Min. Res., Yichang, Hubei Prov., China.

The 40 W-Sn deposits in southern China are divided into three types based on more than 500 oxygen isotope compositions of minerals and rocks, and considerable hydrogen, sulfur, carbon and lead isotope data in the deposits:

(1) Reequilibrium magmatic water W-Sn veins closely related to W-Sn type granitoids with high ^{18}O and the richest radiogenic Pb, Sr. In these deposits, including Xihuashan, etc., the $\delta^{18}O$ values in quartz samples in the main ore-forming stage are from +11 to +13‰; wolframites have $\delta^{18}O$ value ranging from +4 to +7‰. Calculated $\delta^{18}O$ values for fluids in equilibrium with the quartz range from +4.5 to +8.5‰, and the $\delta D(H_2O)$ values of the fluid inclusions in the quartz range from -40 to -70‰. The ^{34}S values of sulfides are about 0‰, et al.

(2) Mesozoic meteoric water hydrothermal W-Sn deposits are of veinlet disseminated or breccia style. In the deposits, quartz and wolframite have $\delta^{18}O$ values ranging from +10 to +7 and +2 to -2‰, et al.

(3) Stratiform W-Sn deposits (such as Woxi, Ferigling, etc.) O values of quartz and scheelite in these deposits are about +20 and +3‰, respectively. The $\delta^{34}S$ values vary within the stratigraphic sequences. The origin of the stratiform W-Sn deposit is related to submarine exhalative activity.

Two calibration equilibrium curves and equation have been obtained:

$$1000/n\ \alpha(2\text{-wf}) = 2.565 \times 10^7 T^{-2} - 7.28 \times 10^4 T^{-1} + 57.27$$

$$1000/n\ \alpha(\text{wf-}H_2O) = 2.285 \times 10^7 T^{-2} + 7.49 \times 10^4 T^{-1} - 61.79.$$

(Author's abstract)

ZHANG, Ligang, 1988, Oxygen isotope studies of wolframite in tungsten ore deposits of south China: Geochemistry (Chinese), v. 7, p. 109-119. Author at Yichang Inst. Geol. & Min. Resources, Ministry of Geol. & Min. Resources, PRC.

Based on the oxygen isotopic compositions of 133 wolframite samples and 110 quartz samples collected from 30 tungsten ore deposits in south China, in conjunction with δD values and other data, these deposits can be divided into four types.

(1) Reequilibrated magmatic water-hydrothermal tungsten ore deposits. The $\delta^{18}O$ values of wolframite and quartz samples from this type of tungsten ore deposits are about +5 - +12‰, respectively. The calculated $\delta^{18}O(H_2O)$ values of ore fluids in equilibrium with quartz are about +6.5‰, and the $\delta D(H_2O)$ values of fluid inclusions in quartz range from -40 to -70‰.

(2) Meteoric water-hydrothermal tungsten ore deposits. The $\delta^{18}O$ values of wolframite in this type of tungsten deposits are around -1‰.

(3) Stratiform tungsten ore deposits. In these deposits, the $\delta^{18}O$ values of quartz and wolframite are about +17 and +3‰, respectively. It is considered that these stratiform tungsten ore deposits are genetically related to submarine hot-spring activities.

(4) Complex mixed-hydrothermal tungsten ore deposits. These tungsten ore deposits are characterized by multi-staged mineralization. The $\delta^{18}O$ values of early wolframite are around +5‰, but of later wolframite are lower than +4‰, indicating that the early wolframite was precipitated from reequilibrated magmatic water-hydrothermal solutions and the late one from the mixture of hydrothermal solutions with meteoric waters or mainly from meteoric waters.

Based on the $\delta^{18}O$ values of the coexisting quartz and wolframite and T data, two calibration equilibrium curves have been constructed, and the corresponding equations have been obtained:

$$1000 \ln \alpha(Q\text{-}Wf) = 2.565 \times 10^7 T^{-2} - 7.28 \times 10^4 T^{-1} + 57.27$$

$$1000 \ln \alpha(Wf\text{-}H_2O) = -2.285 \times 10^7 T^{-2} + 7.49 \times 10^4 T^{-1} - 61.79.$$

(Author's abstract)

ZHANG, Wenhuai and YANG, Weiran, 1988, Application of fluid inclusions in tectonic geology: Geochemistry (Chinese), v. 7, p. 183-188. Authors at Wuhan College of Geol., PRC.

The release of thermal fluids is expected during tectonic movement. These thermal fluids may be trapped by minerals (newly formed or recrystallized) to form fluid inclusions. The aim of this paper is to discuss the tectonic relations between the North China Platform and the Qinling Geosyncline based mainly on the fluid inclusion data. Some preliminary conclusions have been drawn as follows:

1. Recognized between the platform and the geosyncline are several tectonic belts, each of which has different characteristics with respect to fluid inclusions.

2. Various tectonic belts are bounded by the fault, on both sides of which fluid inclusions found are considerably different.

3. Research on fluid inclusions provides further information on the history of tectonic evolution of the North China Platform and the Qinling Geosyncline.

This work is an initial attempt to the study of tectonic geology in terms of fluid inclusion data. (Authors' abstract)

ZHANG, Yigang, 1988, Experimental determination of the PVTX properties of geochemically expected fluid systems by the method of synthetic fluid inclusions: homogeneous and immiscible phase areas: PhD dissertation, Inst. Nat'l.

Polytech. de Lorraine Center de Recherches Pétrogr. & Géochim., 211 pp. (in French; English abstract).

General direction of research: Fluid inclusions, small cavities in minerals which contain minute quantities of aqueous fluids and gases, constitute a very important tool by which geologists and geochemists can reconstruct the history of the minerals containing them. For decades, earth scientists have used fluid inclusions to interpret the T, P, and fluid compositions present during the formation and subsequent evolution of crustal rocks. These studies, however, require experimental data concerning the properties of supercritical fluids if the measurements made on natural fluid inclusions are to be interpreted. Such experimental research is the focus of the work. The technique uses synthetic fluid inclusions that are formed in fractured quartz prisms equilibrated with fluids of various composition at elevated T and P. In particular, the PVT properties of fluids in the $NaCl-KCl-CaCl_2-H_2O$ and $LiCl-H_2O$ systems and immiscibility in the $CaCl_2-H_2O-CO_2$ system were investigated.

PVT properties of $NaCl-KCl-CaCl_2-LiCl-H_2O$ fluids: The use of natural fluid inclusions in determining the T-P conditions of mineral formation requires experimental PVT data. These data are lacking under hydrothermal conditions for even many of the simple binary systems such as $KCl-H_2O$, $CaCl_2-H_2O$ and $LiCl-H_2O$. The data resulting for different investigations of the most thoroughly-studied systems, $NaCl-H_2O$, are inconsistent. Th of synthetic fluid inclusions formed at hydrothermal T and P for the systems $NaCl-H_2O$, $KCl-H_2O$, $CaCl_2-H_2O$, $LiCl-H_2O$ and H_2O have been systematically determined. These experiments formed the data base for the development of a general equation by which Th can be described as a function of T, P, solute concentration, and solute type. This function can also be utilized to compute Th of mixtures of these solutes. These data were then used to compute the PVT properties of the fluids, and agreement with existing data on the H_2O and $NaCl-H_2O$ systems of Burnham et al. (1969) and Hilbert (1979) were excellent. These results provide for the first time a firm foundation on which geologists studying natural fluid inclusions can make accurate T-P determinations of fluid entrapment.

Immiscibility in the $CaCl_2-H_2O-CO_2$: The appearance of fluid immiscibility in hydrothermal fluids with subsequent separation of the two fluid phases has profound petrologic importance as this process provides a mechanism by which fluids can be substantially enriched or depleted in important rock-forming components. Little, however, is known concerning the T-P-X limits of immiscible fluids. The $CaCl_2-H_2O-CO_2$ system has been experimentally investigated and the results indicate that immiscibility in fluids in this system extends to higher P and lower T than previously considered. The $CaCl_2$ was highly partitioned in favor of the denser phase, but unlike lower immiscible fluids existing at lower P, significant concentrations of H_2O occur in the CO_2-rich fluids. Metamorphic petrologists, in light of these data, must now take immiscibility into consideration when developing theoretical mass transport models for rocks in the Earth's crust. (Author's abstract)

ZHANG, Y.G. and FRANTZ, J.D., 1988a Experimental study of fluid unmixing in the system $CaCl_2-H_2O-CO_2$, using synthetic fluid inclusions (abst.): Chem. Geol., v. 70, p. 161. First author at ENSG-CRPG, B.P. 452, 54001 Nancy cedex, France.

Although skarns have been intensively studied from a mineralogical point of view, the actual mechanisms of the interactions between minerals and fluids are poorly understood. In particular, the possible effects of immiscibility during the formation of skarns has not been seriously examined yet. Still, immiscibility in hydrothermal fluids is a common phenomenon, responsible for many spectacular geochemical processes in igneous and metamorphic environments.

In skarns, the fluid systems H_2O-$CaCl_2$ and H_2O-CO_2-$CaCl_2$ are of particular interest. Using the synthetic fluid inclusion technique, the compositional boundaries of the immiscibility field have been determined at 600 and 700°C, 1 and 2 kbar (binary H_2O-$CaCl_2$). The simple presence of two types of inclusions indicates the occurrence of unmixing. The compositional boundaries are inferred from ice (binary) or clathrate (ternary) Tm.

The results indicate that the immiscibility domain in the binary system extends to much higher P than that of the H_2O-NaCl system with similar salt contents. Adding CO_2 further expands the immiscibility field. The data hereunder provide an example of the location of the ternary solvus (21 wt% $CaCl_2$ in the aqueous phase):

	1 kbar	2 kbar	3 kbar
500°C	6	23	31
600°C	0	15	23

(numbers indicate the wt% CO_2 at the boundary).

The location of the tie-lines within the two phase region has been estimated from the Th of the liquid-vapor CO_2-rich phase, and from the volumic ratio Vgas/Vliq in the vapor-rich inclusions. The obtained data indicate strong partitioning of $CaCl_2$ toward the aqueous (liquid) phase.

The major result of this work is that, unless high P and moderate T are concerned, fluid unmixing must be a common process during skarn formation, with all the consequences concerning the partition of the aqueous components between the liquid, the vapor and the solids. (Authors' abstract)

ZHANG, Y.G. and FRANTZ, J.D., 1988b Experimental studies of fluid immiscibility in the system $CaCl_2$-HCl-H_2O-CO_2 under hydrothermal conditions using synthetic fluid inclusions: Terra Cognita, v. 8, no. 1, p. 82.

See previous item. (E.R.)

ZHANG, Y.G. and FRANTZ, J.D., 1988c Experimental studies of fluid immiscibility in the system $CaCl_2$-HCl-H_2O-CO_2 under hydrothermal conditions using synthetic fluid inclusions (abst.): Terra cognita, v. 8, p. 82. Authors at Geophys. Lab., 2801 Upton St., N.W., Washington, DC 20008, USA.

Immiscibility in hydrothermal fluids is responsible for many spectacular petrological and geochemical phenomena in metamorphic and igneous environments. Of special interest is the immiscible behavior of $CaCl_2$-HCl-H_2O-CO_2 fluids due to their possible role in the of skarn deposits and acid metasomatism. Using standard synthetic fluid inclusion techniques the compositional limits of immiscibility were determined by the presence of either one or two different types of inclusions. Using 18.2 wt% $CaCl_2$-H_2O solutions, the location of the solvus as a function of T and P occurs at the following CO_2 compositions (values for 500 and 600°C, respectively): 1000 bars - 6%, 2%; 2000 bars - 23%, 19%; 3000 bars - 35%, 41%. The results indicate that the solvus is strongly P dependent but only slightly dependent on T in this region. The location of the tie lines within the two-phase fluid region is critical to our understanding of the partitioning of compounds between the two phases. Measurements were made on the relative volumes of the vapor and liquid in the vapor-rich inclusion type, of the Th of liquid-gaseous CO_2, and mass spectrometry. All three methods show steeply-dipping tie lines with respect to the H_2O-CO_2 base of the $CaCl_2$-H_2O-CO_2 ternary diagram indicating extensive partitioning of $CaCl_2$ in favor of the liquid-rich phase. Attempts are being made to use a quadrupole mass spectrometer to analyze the bimodal distribution of the gases (in AMU) in the two inclusion types and to calibrate this method. (Authors' abstract)

ZHANG, Y.-G. and FRANTZ, J.D., 1988a Experimental determination of the compositional limits of immiscibility in the system $CaCl_2$-H_2O-CO_2: Carnegie Inst. Washington Ann. Rept. Director 1987/1988, p. 57-62.

The limits of immiscibility in the system are determined at 600°C and 1000, 1500, 2000, and 3000 bars. Also, the liquid/vapor curves as a function of T and P for 500-700°C and 1000-3000 bars. (E.R.)

ZHANG, Y.G. and WEISBROD, A., 1988, Experimental investigations of PVTX and immiscibility in the system H_2O-LiCl, using the synthetic fluid inclusions technique (abst.): Chem. Geol., v. 70, p. 166. Authors at ENSG-CRPG, BP 452, 54001 Nancy cedex, France.

Lithium is a common component in late magmatic and hydrothermal processes associated with highly differentiated and specialized granites.

In the Echassières District (French Massif Central), evidence of significant contents of lithium in aqueous phases is attested by very low Te (<60°C) measured in early fluid inclusions from the Beauvoir granite (Aissa et al., 1987). In order to estimate the effect of lithium in such systems, the poorly known H_2O-LiCl system has been investigated, using the synthetic fluid inclusion technique.

1. Isochores - Lines of constant homogenization temperature (LC Th) have been determined at 500°C, 1.0, 1.5 and 2 kbar, for 2 and 4.5 mol LiCl. The experimental results show that the slopes of the LC Th are similar to those obtained on the H_2O-NaCl and H_2O-KCl systems (Zhang and Frantz, 1987), at the same molalities. This means that, for a given molality and Th, the H_2O-LiCl, isochores are identical to those of the H_2O-NaCl and K_2O-KCl, although the real densities are different indeed.

2. Immiscibility - The immiscibility domain in the H_2O-LiCl system has been investigated at 500 and 600°C, 400 to 500 bar. The results indicate that, for a given molality, the boundary of the liquid + vapor immiscibility domain is close to that obtained it the system H_2O-NaCl, at least at 500°C (Rosenhauer and Bischoff, 1987) and 600°C (Sourirajan and Kennedy, 1962).

Taking these results into account permits to refine the TPX evolution of magmas and fluids associated with Li-rich granites such as the Beauvoir intrusion. (Authors' abstract)

ZHARIKOV, V.A., IVANOV, I.P., OMEL'YANENKO, B.I., RED'KIN, A.F. and YUDINTSEV, S.V., 1987, Experimental study of the solubility of uraninite in granitic melts and fluid solutions at high pressures and temperatures: Geol. Rudnykh Mestor., 1987, no. 4, p. 3-12 (in Russian; translated in Int'l. Geol. Review, v. 29, no. 8, p. 997-1004).

ZHENG, Yongfei, ZHANG, Zuhuan and SHEN, Weizhou, 1988, Physicochemical condition of mineralizing formation in the No. 6217 uranium deposit and significance of the redization (abst.): V.M. Goldschmidt Conf., Program and Abst., May 11-13, 1988, Baltimore, MD, p. 85. Authors at Dept. Geol., Nanjing Univ., Nanjing, China.

No. 6217 uranium deposit, located in the contact zone of the two genetic types of granitoids in South China, is a hydrothermal uranium deposit. The wall-rock alteration is determined to vary from alkalic replacement to greisenization to redization [hematization] to greenization to silicification to fluoritization to carbonatization. The uranium of the ore is in the form of both pitchblende and adsorbate, and accompanying metallic minerals are mainly pyrite and hematite. Composition and Th of inclusions in gangue minerals formed in different mineralizing stages are measured and thermodynamical calculation is performed. The combined results indicate that the mineralization formed under: T 150-250°C, P 130-310 atm, oxygen fugacity 10^{-44} - 10^{-39} atm, sulfur fugacity 10^{-14} - 10^{-6} atm, pH 5.45-7.46 and Eh -0.640 - -0.704 V; uranium in the ore-bearing fluid migrated dominantly in the form of $[UO_2(CO_3)]^{2-}$ and $[UO_2F_4]2^{2-}$; hydrothermal solution in pre-ore stage has higher oxygen fugacity and higher uranium content (the uranium exists in the high-valence state). Investigation of paragenetic association and chemical composition of minerals coexisting with the pitchblende and uranium-bearing ore is coupled with the thermodynamical calculation to demonstrate that the redization is produced by oxidizing of the alkalic metasomatic fluid to the wall-rock and the redizated rock favored the uranium mineralization rather than its consequence which is usually suggested. Available reactions are supposed as follows:

$[UO_2(CO_3)]^{2-} + Fe_2O_3 + 4H_2S + 2Ca^{2+} \rightarrow UO_2\downarrow + 2FeS_2 + 2CaCO_3 + 3H_2O + 2H^+$

$[UO_2F_4]^{2-} + Fe_2O_3 + 4H_2S + 2Ca^{2+} \rightarrow UO_2\downarrow + 2FeS_2 + 2CaF_2 + 3H_2O + 2H^+$.

(Authors' abstract)

ZHOU, Shili, 1988, Significance of "facies change peak" in decrepitate curves of fluid inclusions: Bull. Nanjing Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., v. 9, no. 3, p. 93-102 (in Chinese; English summary).

ZHU, Fengsan, 1988, Study on the geochemistry, lithology and metallogeny of Zhao-Ye migmatitic hydrothermal gold deposits belt (abst.): Bicentennial Gold 88, Geol. Soc. Australia Abst. Series No. 23, p. 336-338. Author at Changchun Gold Res. Inst. of M.M.I., 54, South Lake Rd., Changchun, Jilin Province, China.

Fluid inclusions showed the ore-bearing hydrothermal solution is Ca^{2+} - HCO_3^- type. The diagenetic hydrothermal solution is Na-K-Cl type, i.e., chloride type, and is quite different from the ore-bearing solution. The T of ore forming varies from 400°-150°C, and gradually decreases through premineralization period and I-IV stages of mineralization. Stage II and III are the main mineralizing stages, the T ranges 320°-180°C and 320°-150°C respectively. The P during mineralization from 1068 atm to shallow depths. (From the author's abstract)

ZIMMERMANN, J.L., JAMBON, Albert and GUYETAND, Gilbert, 1988, Manometric and mass-spectrometric analysis of fluids in geological materials: Geochem. J., v. 22, no. 1, p. 9-21 (in English). Authors at Cent. Rech. Petrogr. Geochim., CNRS, 54501 Vandoeuvre les Nancy, France.

A procedure of volatile analysis in rocks which permits quantitative estimation of all the volatile species of any geologic interest is presented and illustrated by several examples. Gas extraction is performed either by vacuum crushing or heating. A separation line with cold traps, oxidation (CO to CO_2) and redn. (H_2O to H_2) furnaces permits sep. several fractions. At the end of each separation phase, the P in the line is measured with a capacitance manometer before analysis of the gas mixture with a mass spectrometer. Calibration is done periodically by using standard gases stored in gauged bottles. The detection limits are 0.5-1 x 10^{-7} mol H_2O, 0.3 x 1^{-7} mol CO_2, and ~0.2 x 10^{-7} mol for H_2, N_2, CO, CH_4, and Ar. Further species like organic compounds, SO_2 and H_2S are detected but not determined. In the case of H_2O and CO_2 the reproducibility is >4%. The conjunction of vacuum crushing, stepwise heating and size fraction analysis permits separating components like: dissolved, adsorbed and vesicle trapped. In particular, effects of adsorption were evaluated: it is a serious problem for species like CO_2 and H_2O with finely crushed material. H_2 and CO detected after thermal extn. when organic compounds are present in the sample reflect organic decomposition rather than any thermodynamic equilibrium attained upon rock formation. (C.A. 109: 234421j)

ZINDLER, Alan and JAGOUTZ, Emil, 1988, Mantle cryptology: Geochim. Cosmo. Acta, v. 52, p. 319-333. First author at Lamont-Doherty Geol. Observatory, Dept. Geol. Sci., Columbia Univ., Palisades, NY 10964, USA.

A group of anhydrous peridotites from Peridot Mesa, Arizona, document isotopic and trace element heterogeneity in the source mantle. LREE enrichments in two spinel peridotites may have occurred immediately prior to entrainment through interaction with a melt similar to the host basanite. One sample, MORB-source-like in its trace element and isotopic character, has escaped this enrichment and may have evolved via a single melt depletion event acting on a relatively unfractionated parental composition ~900 m.y. ago.

Detailed characterization of inclusion-free peridotite phases, and washed and unwashed whole-rock samples, verifies the presence of a ubiquitous secondary contaminant which derives from interaction of the peridotites with local ground waters and host magma. Once the veil of this contamination is removed, coexisting phases are found to be in isotopic equilibrium. Further, a comparison of washed whole rocks and calculated clean-bulk compositions documents the occurrence of an important intragranular fluid-hosted trace element component. For the very incompatible elements (K, Rb, Cs, and Ba, and probably U, Th, Pb and gaseous components as well) this component dominates the nodule budget for two of the three samples studied in detail.

Production of basaltic magmas from "fertile" but incompatible-element-depleted peridotite (such as PA-65G and PA-15A, two of the samples studied here) requires the action of melting processes such as those recently proposed by McKenzie (1985) and O'Hara (1985). The distinctive feature of these models is that they call on effectively larger source volumes for more incompatible elements. In this context, depletions of incompatible trace elements in MORB source mantle will be more extreme than has heretofore been suspected. This would essentially preclude the long-term total isolation of a MORB source mantle above the 670 km seismic discontinuity. (Authors' abstract)

ZINS-PAWLAS, M.P. and FRITZ, B., 1988, A thermodynamic quartz geothermometer for brines (abst.): Terra cognita, v. 8, p. 190. Authors at Centre de Sédimen. & Géochimie de la Surface (CNRS), Strasbourg, France.

Geothermal waters reaching the earth's surface at the time of geothermal exploratory drilling are always taken at an emersion T lower than the T of the reservoir from which they are produced. The purpose of geothermometry calculations is to find the original reservoir T at depth. Solutions which have been in contact with the reservoir rocks for a long enough time may have reached a thermodynamic equilibrium. As quartz is often abundant in the rock environment of the deep fluids, it allows us to use quartz geothermometry for T greater than 160°C.

However, the geothermometry normally uses an empirical relation between the molality of silica and the T, without effect of the salinity of the fluids. To avoid this uncertainty, a new goethermometer for brines is proposed. It uses the calculation of the activity of silica and takes into account the chemistry of the solution.

This geothermometer was used on fluids from the geothermal well of Strasbourg-Cronenbourg which targets Triassic sandstones (Bundsandstein) at depths between -2700 m and -3200 m. The extracted solution is a NaCl brine, enriched in Ca and K, with total dissolved load of 108.0 g/kg of water. During production tests, the T calculated from the classical geothermometer varied between 140°C and 160°C at the time of the last pumping test when total silica content was 2.38 mMoles/l. The pH at depth was estimated at 6.90, so that the H_4SiO_4 silica species is dominant.

The quartz geothermometer applied to this brine indicates a T of 182°C, as a thermodynamic equilibrium T for the quartz-brine system in good agreement with the results obtained from sulphur and oxygen isotopic studies. (Authors' abstract)

ZOLOTUKHIN, V.V., KOVYAZIN, S.V., SHCHERBAKOVA, Z.V. and VASIL'EV, Yu.R., 1988, Peculiarities of compositions and temperatures of basite and ultramafic deep-seated melts on the Siberian Platform, in Kalyuzhnyi et al., eds., Proc. 7th All-Union Conf. on Thermobarometry and Geochemistry of Mineral-Forming Fluid, L'vov, Sept. 30-Oct. 2, 1985: Kiev, Naukova Dumka Press (ISBN 5-12-001072-5), p. 20-28 (in Russian).

Full paper for abstract published in Fluid Inclusion Research, v. 18, 1985, p. 478-479. (E.R.)

ZOTOV, A. and BARANOVA, N., 1988, Thermodynamics of the gold chloride complexes under 350 to 500°C and the pressure of 500 to 1500 bars (abst.): Terra cognita, v. 8, p. 185. First author at The Inst. Geol. of Ore Deposits, Petrogr., Min. & Geochem., USSR Acad. Sci., Moscow, USSR.

The solubility of metallic Au in solutions of HCl + KCl under 350 to 500°C, 500 to 1500 bars and controlled oxygen fugacity 10^{-25} - 10^{-29} bar was studied using the autoclave method. It was established that in 0.006 - 0.3 m HCl solutions Au exists in the form of hydroxocomplexes AuOH° under 450°C. The solubility of Au is rising in HCl $\geqslant$0.006 m solutions containing KCl (0.1 - 3 m), which is caused by formation of such chloride complexes as $AuCl_2^-$. The equilibrium constants of the Au solubility reaction were determined from the equation: $Au(s) + HCl^\circ_{(aq)} + Cl^-_{(aq)} + 0.25\ O_{2(g)} = AuCl^-_{2(aq)} + 0.5H_2O$.

lg K°(450°, 500 bars) = 2.98 ± 0.07 ; lg K°(450°, 1000 bars) = 2.76 ± 0.04 ;
lg K°(450°, 1500 bars) = 2.59 ± 0.12 ; lg K°(500°, 1000 bars) = 2.48 ± 0.18.

It seems that Au chloride complex is the main form of Au in the hydrothermal fluids without sulfide species in the acidic and weak acidic media. (Authors' abstract)

Appendix

(Late additions)

BISCHOFF, J.L. and ROSENBAUER, R.J., 1987, Phase separation in sea floor geothermal systems: An experimental study of the effects on metal transport: Am. J. Sci., v. 287, p. 953-978. Authors at U.S. Geol. Survey, Menlo Park, CA 94025.

The effects of vapor-liquid phase separation on metal mobilization in sea floor geothermal systems were studied by reacting natural and evolved sea water with crystalline basalt from the Juan de Fuca Ridge. After equilibration in the single-phase region at 406°C, 330 bars, each system was heated to the two-phase boundary (condensation curve) and then expanded and cooled along an adiabat in the two-phase region to sea floor conditions near 390°C and 250 bars. Phase separation was, in effect, a closed-system process by which approximately half the mass of H_2O transferred into the vapor phase, while the volume of the system was allowed to expand. Results indicate that during phase separation and adiabatic cooling both the acidity and the concentration of heavy metals increased in the liquid phase. Moreover, the vapor phase contained surprisingly high concentrations of SiO_2 and Fe and other heavy metals. Although some SiO_2 was precipitated the system became increasingly undersaturated with respect to pyrite and, by analogy, other heavy metal sulfides, as a consequence of expansion and phase separation. Distribution of the gases H_2, CO_2, and H_2S between the vapor and liquid are reasonably consistent with extrapolated Henry's Law constants. Redox conditions and Fe-mineral equilibria are represented reasonably well by concentrations of H_2 and H_2S. The unexpectedly high concentrations of heavy metals in the vapor at such moderate P and T suggest that unknown species control solubility in the vapor phase and imply that the role of vapor transport in ore deposition may be important even in the shallower portions of the Earth's crust. (Author's abstract)

BOWMAN, M.W. and GOLDSTEIN, R.H., 1988, Sandstone diagenesis in interbedded carbonate-siliciclastic sequence, Virgilian Holder Formation, New Mexico (abst.): AAPG Bull., v. 72, p. 165. Authors at Univ. Kansas, Lawrence, KS.

The Pennsylvanian (Virgilian) Holder Formation, New Mexico, consists of shales and sandstones interbedded with paleosol-capped limestones. Approximately 10 of these cycles were described in 13 stratigraphic sections. Analyses of paleosols on limestone surfaces and sedimentary structures in overlying sandstones indicate an upward transition for nonmarine to marine conditions. Secondary petroleum-filled fluid inclusions in later fracture-fill cements indicate petroleum migrated after most porosity was occluded. (From the authors' abstract by H.E.B.)

COOK, K.H., 1986, Conodont color alteration: A possible exploration tool for ore deposits: MS thesis, New Mexico Inst. Mining & Technology, Socorro, NM.

[A study] relating the alteration of conodont-color to thermal environments associated with the deposition of economic minerals. The Hansonburg Mississippi Valley-type deposit and Continental Cu skarn deposit were studied to determine whether a relationship exists between the alteration of conodont-color and hydrothermal activity. The Central Tennessee Mississippi Valley-type deposit was studied to determine whether this relationship could be used as an exploration tool for blind ore deposits.

Carbonate rock, silica, and hydrothermally deposited minerals were collected at each deposit for measurement of conodont-color, size of silica-crystallites, and fluid inclusion T. Conodonts were separated from host carbonate rocks and conodont color alteration indices (CAI) were determined using a set of field standards. Fluid inclusion and silica-crystallite geothermometry were used as independent checks of temperatures for these deposits.

In the Hansonburg mining district, conodont CAI increase from 1 to 3 toward the deposit, with 3 being closest to the mineralization. CAI of 1 represent background values, and CAI from 1.5 to 3 represent anomalous values. These anomalous values surround the deposits and extend up to 400 meters from known occurrences of [mineralization].

[CAI were found to change] towards the Hanover-Fierro stock, which is genetically related to Cu mineralization. These CAI surround the intrusive extending up to 5 kilometers from the pluton, suggesting that this area was extensively heated during the emplacement of the stock.

In the Central Tennessee mining district CAI from 1 to 2.5 were measured. CAI of 1 represent background values, and CAI of 1.5, 2, and 2.5 represent anomalous values. Anomalous CAI are regionally extensive and stratigraphically distributed, with 1.5 to 2 occurring low in the stratigraphic section and 2.5 occurring high in the stratigraphic section. The stratified nature of CAI in the Central Tennessee mining district suggests that the highest T were located near the top of the hydrothermal system.

Published T (Epstein et al., 1977) associated with anomalous CAI are in close agreement with fluid inclusion Th measured in hydrothermally deposited minerals. T determined from the size of silica-crystallites do not correlate well with fluid inclusion Th or the published T associated with anomalous CAI.

I contend that the anomalous CAI observed near mineral deposits in this thesis indicate that alteration of conodont [color is indicative of the effects of hydrothermal activity]. (Author's abstract, with some missing parts added by E.R.)

COOKRO, T.M., SILBERMAN, M.L. and BERGER, B.R., 1988, Gold-tungsten-bearing hydrothermal deposits in the Yellow Pine mining district, Idaho, in Bulk mineable precious metal deposits of the western United States, R.W. Schafer, J.J. Cooper and P.G. Vikre, eds., Symp. Proc., Geol. Soc. Nevada, Apr. 6-8, 1987, p. 577-624. Authors at U.S. Geol. Survey, P.O. Box 25046, MS 937, Denver Fed. Center, Denver, CO 80225.

Hydrothermally altered and mineralized rocks in the Yellow Pine mining district, located near Stibnite, in central Idaho, contain anomalous concentrations of Au, W, Ag, As, Sb, and B and irregular enrichment of Cr and Mn. Hg content is erratic and is highest in the structurally and topographically highest parts of the district. The mineralization and alteration are hosted in granitic rocks of the Cretaceous Idaho Batholith and in pre-Mesozoic metamorphic rocks included within the batholith.

O isotope ratios of stockwork vein quartz are in a range +10 to +13 ^{18}O; these values are similar to O isotope ratios found in quartz from lode-Au deposits hosted in metamorphic rocks. However, deuterium-hydrogen ratios (D) of inclusion fluids are in the range -100 to -114 D per mil and are typical of meteoric quartz-precipitating fluids.

The altered and mineralized rocks in the Yellow Pine district had a complex hydrothermal history, but the data suggest that the last stage of alteration and mineralization resulted from circulation of meteoric fluids along regional shear zones. (From the authors' abstract)

A preliminary fluid inclusion survey reveals some characteristics of the quartz within the district characteristic of the two environments, deep and shallow. The deep-environment quartz is characterized by (1) ubiquitous, wispy textures of S inclusions defining millions of healed microfractures which cause the quartz to be cloudy or milky in appearance, (2) the presence of several one-phase aqueous inclusions, concentrations of inclusions with inconsistent liquid to vapor volumetric ratios at grain boundaries, (3) the presence of healed microfractures with inclusions oriented perpendicular to planes, and (4) the presence of gases (CO_2?, CH_4?, and N_2?) under P within many inclusions. Sphalerite is sparse in quartz from a deep environment.

Quartz veins containing inclusions typical of a shallow depositional environment cross-cut the milky quartz veins. The shallow quartz characteristically has cockscomb, cryptocrystalline, or chalcedonic texture. Inclusions in cryptocrystalline and chalcedonic quartz are characteristically smaller than 2 mm [2 μm?] while those in open-space-filling quartz are characteristically liquid-rich, two-phase, P aqueous inclusions. The shallow quartz is the dominant variety of quartz deposited during mineralization. The cryptocrystalline and chalcedonic quartz in some samples from the Yellow Pine mine have inclusions that are too small to study; this is common with quartz thought to have formed at T <200°C. Scheelite, stibnite, and arsenopyrite are included within the shallow quartz. (From the authors' text)

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 here-to-fore published.

BULANOVA, G.P., NOVGORODOVA, P.G. and PAVLOVA, L.A., 1988, First finding of melt inclusion in diamond from the pipe "Mir': Geokhimiya, no. 5, p. 756-765 (in Russian; English abstract). Authors at Geol. Inst. of the Yakutian Div. of Siberian Br. of Acad. Sci. USSR, Yakutsk, USSR. (Translation by A. Kozlowski)

Studies of the syngenetic inclusions in diamonds have great importance in the solution of the problem of their genesis. The studies of minerals included in natural diamonds are reviewed by Sobolev [1], Harris and Gurney [2], Meyer [3] and other authors. These works describe essentially studies of macroinclusions, whereas microinclusions (size <20 μm) in diamonds up to now practically were not considered.

The inclusion preparation method used by us, by means of the gradual grinding of the diamond [4] permits studies of microscopic size inclusions, which were lost when other extraction methods (combustion or crushing) were applied. Studies of the "central" inclusions, mostly having microscopic sizes, showed their essential difference from the generally known varieties of syngenetic inclusions in diamonds [4]. The aim of the present work is the further study of such inclusions.

The diamond monocrystal studied by us was a colorless flattened octahedron without visible macrodefects (fractures), with hatching of sheaf habit along the edges and zonal birefringence. A group of small colorless inclusions 8-18 μm in size occurred in its central zone. Several inclusions of the same type were found in the intermediate and marginal parts of the diamond.

During the process of the gradual grinding on the surface, ten inclusions belonging to the eclogitic paragenesis were analyzed. Results of studies of these inclusions have been presented by Bulanova et al. [5]. In the present paper special attention is paid to the composition and pecularities of the "central" microinclusion from this diamond, having typical features of partly crystallized P melt inclusions.

The inclusion composition was studied by means of the microanalytical complex Camebax-micro with computer PDP 11/23 and energy spectrometer Kevex. The analysis was performed in a mode permitting simultaneous wavelength dispersion and energy dispersion measurements. The accelerating potential was 15 kV and the electron current 18 nA. The excitation area diameter (ca. 2 to 3 μm) was controlled visually by the diameter of the luminescence spot on the diamond. The contents of Na, Mg, Si, K, Ti, Mn and Fe were determined quantitatively. Oxide concentrations were calculated stoichiometrically and matrix effects were corrected using a program supplied to the computer PDP 11/23.

Results of the Studies

Central polyphase inclusion.

The inclusion had a hexagonal platy habit (18 x 18 μm) and was associated with a small internal fracture. On the contact with the diamond the inclusion was covered by a black film (graphite) precluding optical determinations. Reflected light observations revealed a polyphase structure. The central inclusion part bears a pale-yellow ore mineral of a rectangular habit and ca. 4 μm in size. This mineral is surrounded by a greenish zone ca. 3 μm wide, the remaining inclusion part is gray.

Phase composition. The microprobe analysis of the inclusion confirmed its polyphase composition. It is visible on the distribution patterns of the X-ray Kα radiation of Ti, Si, Fe, Al and K (Fig. 1a-e). These data were the basis of the schematic drawing of the phase composition of the inclusion (Fig. 1f). Size of the inhomogeneous areas were comparable with the beam spot size or even smaller. Thus, mostly a mixture of phases present in inclusion was analyzed.

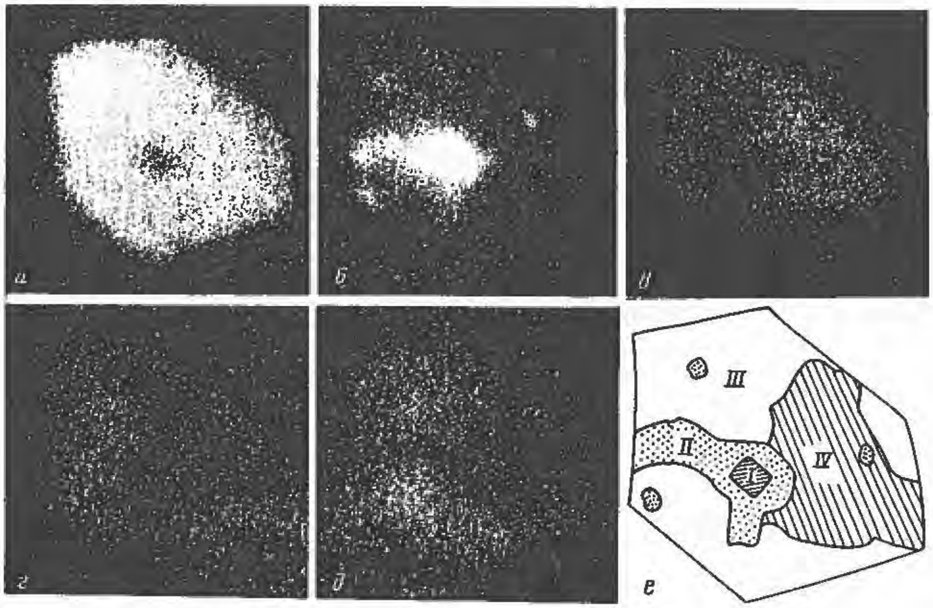


Fig. 1. Melt polyphase inclusion from the central zone of diamond No. 1168. Photos in characteristic X-rays, Kα: Ti (a), Si (b), Fe (c), Al (d), K (e), magnif. x 3200, f - drawing made on the basis of the optic image and X-ray distribution: I- rutile, II - Fe-Ti-Si-phase, III - clinopyroxene and Fe-Ti-Si-phase, IV - clinopyroxene and K-Al-Si-phase (fine mixture).

In spite of the small dimensions, satisfactory analyses were obtained for rutile, clinopyroxene and two phases that were not unambiguously identified. The phases were as follows: 1) iron- and titanium-rich silicate phase (Fe-Ti-Si) forming a zone 2-4 μm wide around the rutile and three small round separate grains in fragments III and IV (Fig. 1b, e); 2) silicate phase bearing K and Al (K-Al-Si) occurring in fine intergrowths with pyroxene; in fragment III (Fig. 1a) one can obtain satisfactory analyses for clinopyroxene and for the K-Al-Si phase, but in fragment IV the analyzed objects were fine intergrowths of these phases.

After some grinding the picture of the phase composition changed a little. In the inclusion center there was again a rutile crystal only 1.5 μm wide. The rim of Fe-Ti-Si phase decreased significantly and its small grains disappeared. The remaining field was filled by a fine mixture of K-Al-Si phase and clinopyroxene.

Thus, the central polyphase inclusion consist of rutile + Fe-Ti-Si phase + K-Al-Si phase + clinopyroxene.

Peculiarities of chemical composition. Fifty analyses were performed on two inclusion sections. Table 1 presents the most representative analyses for every phase of the inclusion.

Rutile has the usual composition, typical of this mineral in diamonds. The admixture of SiO_2 and CaO in rutile probably is caused by trapping of the surrounding phase.

Fe-Ti-Si phase has no phase of analogous composition, either among the inclusions in diamonds or among known minerals. Probably its composition includes volatile components, as is suggested by unstability during action of the electron beam. Radiation intensity in every point of the fragments of the Fe-Ti-Si phase is stable only during 10-15 sec. and the analyzed surface becomes covered by tiny caverns, what may indicate the presence of volatiles.

The only analogy found for the Fe-Ti-Si phase among other natural compounds is its certain similarity to the composition of basic natural glasses. However, the high Ti content distinguishes this phase from natural glasses. This difference may be explained by the specific conditions of formation of the Fe-Ti-Si phase. This phase is inhomogeneous and may bear tiny crystals of phlogopite or rutile in glass. This conclusion appears from experimental works [6-8], where partial crystallization during quenching of basic glasses rich in Fe, Ti and K is reported. Phlogopite and clinopyroxene formed on quenching are richer in Ti and Fe than the primary crystals [7].

Table 1. Chemical composition of the polyphase inclusion from the central zone of the diamond No. 1168

Component	Rutile	Fe-Ti-Si-phase		Clinopyroxene			K-Al-Si-phase		Fine mixture of clinopyroxene and K-Al-Si-phase		
SiO_2	2.87	38.35	40.39	53.63	54.30	51.71	60.48	65.02	55.43	59.52	58.0
TiO_2	90.48	29.81	25.55	1.20	1.23	0.93	1.81	0.62	1.22	2.17	0.8
Al_2O_3	0.69	7.28	7.31	3.59	3.39	1.54	17.45	16.78	9.03	12.7	10.0
Cr_2O_3	0.02	0	0	0.08	0.06	0.04	0	0.04	0	0	0.05
FeO	0.67	9.74	8.36	11.78	10.97	12.45	1.01	1.23	7.06	5.83	6.0
MnO	0	0.03	0	0.15	0.12	0.16	0	0.01	0.06	0.11	0.06
MgO	0.11	2.05	1.35	8.16	10.35	9.54	0.20	0.16	6.06	4.38	6.0
CaO	0.97	4.05	3.16	16.55	16.50	19.46	0.75	0.43	10.22	6.73	8.0
Na_2O	0.02	1.28	1.39	1.93	3.15	1.47	0.59	0.33	1.77	1.76	1.5
K_2O	0.15	1.79	2.68	0.68	0.28	0.19	7.29	6.02	1.61	1.8	3.0
Total	95.98	94.37	90.17	97.74	100.35	97.45	89.59	90.64	92.46	94.98	93.41

K-Al-Si phase is most similar to K-spar, but is not the same as stoichiometric sanidine. Recalculation of three analyses of this phase gives the following oxide ratios $(Na_2O + K_2O):Al_2O_3:SiO_2 = (0.42-0.51):1:(2.96-3.28)$, see Table 1. Moreover, the K-Al-Si phase was unstable under the electron beam and it contained Cl, S and P in variable amounts. Semiquantitative analysis showed that the concentrations range 0.1-1% and 0.1-0.5% respectively. The data indicate that K-Al-Si phase may be a K-high silicate glass.

Inclusions of practically the same composition were described in two diamond crystals of unknown origin [9]. Earlier the present authors published analytical results on an inclusion in a diamond, which were thought to be analyses of K-spar [10]. Analysis of one of the studied inclusions had the stoichiometry of sanidine, but another one gave too low an oxide total and too low K_2O content (Table 2). Inhomogeneous distribution of K_2O in this inclusion, i.e., enrichment in K_2O of the outer zone and the chlorine admixture also indicates that it may consist of melt. Besides, inclusions of similar composition were found in the interstices between pyroxenes and plagioclases of the lunar basalts [11,12].

Clinopyroxene, forming fine intergrowths with the K-Al-Si phase, is characterized by variable values of Fe/(Fe + Mg), from 36.6 to 45% and Ca/(Ca + Mg) from 56 to 60%; it bears less Na and Al than omphacite, which has Fe/(Fe + Mg) = 25.5% Ca/(Ca + Mg) = 50% and occurs at a distance of only 90-100 μm (Table 3, Fig. 2).

Table 2. Compositions of melt phases from inclusions in diamonds

Component	Polyphase Inclusion 1168				K-Al-Si-phase		
	1	2	3	4	5	[10]	[9]
SiO_2	56.9	59.7	58.3	40.6	67.3	67.8	67
TiO_2	7.1	4.0	5.5	31.6	2.0	1.2	2.5
Al_2O_3	10.0	10.5	10.3	7.7	19.7	21.4	14 - 17
FeO	7.4	6.8	7.1	10.3	1.0	0.6	2 - 3
MnO	0.1	0.1	0.1	-	-	-	-
MgO	4.9	4.1	4.5	2.2	0.2	0.1	1
CaO	8.9	9.2	9.1	4.3	0.9	0.3	-
Na_2O	1.6	1.5	1.5	1.4	0.7	0.5	0.2 - 2.5
K_2O	2.8	2.7	2.7	1.9	8.2	8.0	8.5 - 10
Q	11.1	15.9	13.5	6.7	28.9	33.2	20.2
Or	16.7	16.1	16.4	11.1	48.4	47.3	54.5
Ab	13.6	12.6	13.1	11.8	5.8	4.2	11.5
An	11.7	13.9	12.8	9.2	4.2	1.4	-
Di Wo	13.6	13.2	13.4	5.1	-	-	-
Di En	6.4	5.9	6.1	1.1	0.5	0.2	2.5
Di Fs	7.0	7.2	7.1	4.3	1.8	1.1	4.6
Hyp En	5.8	4.3	5.0	4.4	-	-	-
Hyp Fs	6.7	5.4	6.0	14.5	-	-	-
Rut	7.1	4.0	5.6	31.6	3.8	2.3	4.7
Cor	-	-	-	-	8.2	11.4	3.2

Remarks: 1,2 - bulk compositions calculated from 18 and 21 analyses respectively, in two sections of the inclusion; 3 - average composition; 4 - Fe-Ti-Si phase; 5 - K-Al-Si phase (recalculated to 100%), for the K-Al-Si phase from [9] the calculation of the normative composition CIPW was made with use of the average concentrations of Al_2O_3, FeO, Na_2O and K_2O.

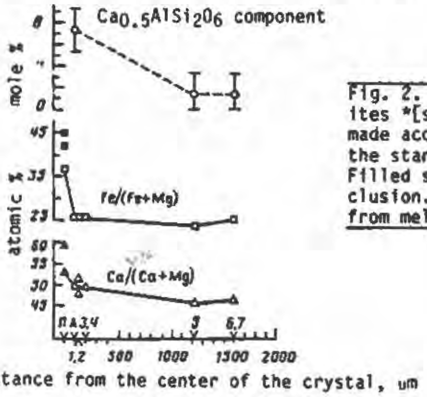


Fig. 2. Composition of the zonally distributed melt inclusions of omphacites *[sic - A.K.] in the diamond No. 1168. Calculation of the composition made according to [17]. Ranges of the Eskola's Ca-molecule content reflect the standard deviation of the SiO_2 determination by electron microprobe [1]. Filled symbols indicate the clinopyroxene composition from the polyphase inclusion. (* Most probably it should read: Composition of clinopyroxenes from melt inclusions and zonal distributed omphacites.)

The results obtained indicate that the polyphase inclusion differs from the group of syngenetic inclusions in diamond. First, the chemical composition of clinopyroxene from this inclusion differs from that of other clinopyroxenes (omphacites), zonally distributed in diamond (Table 3).

On the basis of the chemical composition, the clinopyroxene P formed later than ompacites. Probably it crystallized from a trapped droplet of melt in the diamond crystal that stopped its growth.

The melt nature of the polyphase inclusion is proved by the relations of mineral phases in this inclusion. Most of it consists of the K-Al-Si phase (glass?) with fine crystals of clinopyroxene P of variable composition. The K-Al-Si phase bears S, P and Cl, typical minor elements of silicate glasses. Thus, the central polyphase inclusion consists of an association of phases including crystals (rutile, clinopyroxene) and probably solidified melt of contrasting composition. The nature of formation of the latter is still obscure. The inclusion is undoubtedly primary, because the diamond bears neither larger defects nor fractures contacting the surface. Hence it is a primary, partly crystallized melt inclusion.

Table 3. Chemical composition of inclusions in the diamond 1168

Component	Omphacites				Garnet	Omphacites		Garnet
	A	1	2*	3	4	5	6	7
SiO_2	54.85	55.61	56.07	54.50	39.69	55.63	55.40	38.99
TiO_2	0.26	0.23	0.23	0.19	0.93	0.70	0.72	0.42
Al_2O_3	11.24	12.29	10.26	11.00	20.81	9.22	9.46	21.85
Cr_2O_3	0.10	0	0	0.05	0.20	0.07	0.15	-
FeO	5.22	4.95	4.13	5.26	16.95	5.77	5.85	17.74
MnO	0.08	0.03	0	0	0.29	0.08	0.04	0.42
MgO	8.52	8.18	9.46	8.49	9.66	10.47	9.71	12.74
CaO	11.93	13.23	14.10	12.20	8.77	12.28	11.96	5.31
Na_2O	5.57	4.35	2.12	4.31	0.23	5.37	5.44	0.20
K_2O	0.28	0.29	1.91	0.25	-	0.14	0.22	-
Total	98.05	99.16	98.33	96.25	97.35	99.73	98.93	97.70
Si	1.987	1.983	2.019	2.003	3.014	1.991	1.999	2.972
Al^{IV}	-	-	-	-	-	-	-	-
Ti	0.007	0.006	0.008	0.005	0.055	0.019	0.019	0.024
Al^{VI}	0.480	0.505	0.435	0.476	1.911	0.389	0.402	1.962
Cr	0.003	-	-	0.001	0.001	0.002	-	-
Fe^{3+}	-	-	-	-	0.088	-	-	0.020
Fe^{2+}	0.158	0.148	0.124	0.162	0.016	0.173	0.173	1.107
Mn	0.002	0.001	-	-	0.019	0.002	-	0.027
Mg	0.460	0.435	0.508	0.465	1.121	0.559	0.522	1.447
Ca	0.463	0.505	0.544	0.481	0.732	0.471	0.462	0.433
Na	0.391	0.301	0.148	0.307	0.034	0.372	0.380	0.030
K	0.013	0.013	0.088	0.012	-	0.006	0.010	-
Total	3.966	3.909	3.874	3.912	7.992	3.954	3.967	8.022
f	25.5	25.34	19.62	25.84	49.29	23.57	24.89	43.9
Ca/(Ca + Mg)**	50	55.86	51.71	50.84	25.5	45.73	46.95	14.4

Note: A, 1-4 - central part of the crystal, 5 - intermediate part, 6,7 - outer part.

* Inhomogeneous with respect to K, Na and Al, in association with magnetite(?).

**For garnets the values X^{Gar}_{Ca} is given.

Zonally distributed omphacites and garnets.

Further grinding of the diamond opened an inclusion of omphacite-A occurring 100 μm from the polyphase inclusion (Table 3). Thus, somewhat further from the growth center but within the central part of the diamond, four neighboring inclusions have been found. The largest one (15 x 20 μm, No. 1168-1) and one smaller (10 x 10 μm, No. 1168-2) were omphacites rich in K_2O (Table 3). The smaller inclusion has 1.91% K_2O, an anomalously high content for omphacites. The distribution of the K-Kα and Al-Kα radiation was inhomogeneous throughout the inclusion; there is a possible presence of a second K-rich phase, maybe similar to the K-Al-Si phase from the polyphase inclusion.

Together with the omphacite 1168-2 there are small (3 μm) round opaque inclusions. In reflected light these inclusions are white with yellowish tint, isotropic and with high reflectivity. By an electron microprobe analysis only 72% Fe and 0.3% Co was found, indicating that this mineral may be magnetite. Also omphacite-3 and garnet-4 were analyzed, both from the middle part of the central zone of the diamond crystal. In the intermediate zone of the diamond omphacite-5 was identified and in its peripheral zone - omphacite-6 and garnet-7.

Table 3 presents compositions of all the studied omphacites and garnets and Fig. 2 shows typical changes of the omphacite compositions depending on the distance from the growth center of the diamond. As seen in the drawing such indices as calcium and iron contents in omphacites change slowly but regularly. Thus the iron index of the earliest omphacites equals ca. 25%, the intermediate ones - ca. 23% and the peripherical ones - again ca. 25%. Also one should note the increase of the K_2O content in omphacites: 0.14 to 0.29%.

Garnets from various growth zones differ more in their compositions than omphacites. Garnet-7 from the periphery is lower in Fe, Ca and Ti than garnet-4 from the center of the diamond. In omphacites Ti content increases from the central inclusions to the peripheral ones. The partition coefficient of Ti between garnet and omphacite K_DTiO_2(Gar/Cpx) decreases from 4.9 to 0.6 on approaching the diamond margin.

Discussion of the Results

Nature of the polyphase inclusion.

The evaluation of the bulk inclusion composition as a part of a rutile eclogite melt is interesting for understanding the nature of the inclusion. Evidently, there is a problem as to what degree an inclusion 18 x 18 μm in size may reflect the real composition of such melt. Some doubts are connected with the rutile crystal--whether it existed in the original melt or it crystallized later from this melt like clinopyroxene. If rutile crystallized from the melt portion trapped by the diamond, the melt should have an unusually high original titanium [i.e., TiO_2? - A.K.] content of about 12 wt.%. This disagrees with experimental data [13], which indicate a reverse relation of TiO_2 solubility in silicate melt with pressure. Thus the bulk composition of the melt was calculated supposing that rutile was trapped as a crystal phase together with the melt and rutile was not included in melt composition.

Bulk compositions of melt (1 and 2) given in the Table 2 were obtained by calculation of the average values from analyses performed uniformly on the inclusion surface on every one of the polished surfaces. Correctness of the calculations of the bulk composition is confirmed by its similarity to the composition of the fine mixture of clinopyroxene-P and the K-Al-Si-phase (Table 3). Calculated bulk inclusion composition (Table 2) may be considered to be a peculiar hypersthene andesite. On the basis of theoretical considerations, earlier workers [14][1] presented the opinion that the primary melting product of mantle eclogites was a dacite-andesite magma. The inclusion differs from the known analyses of such rock types in its high TiO_2 and K_2O, and low Al_2O_3 and Na_2O contents. These peculiarities, seemingly, are connected with high solubility of TiO_2 and K_2O in mantle melts [7, 8] and, on the other hand, the presence of Al_2O_3 and Na_2O in the garnet and omphacite structures. The calculated composition of the melt inclusion agrees well with results of the experiments on melting of calc-alkaline rocks under high P. In dry melting conditions the T minimum of solidus and liquidus occurs in the range of andesite composition [15], and experiments performed in the P interval 2.5-4.5 GPa indicate that the composition of such melts is practically unaffected by pressure [16].

Taking into account the importance of the problem of the melt existence during diamond crystallization, one should discuss another possible mode of the polyphase inclusion origin. Let's suppose that a cluster of minerals has been trapped as the central inclusion in the diamond. This cluster could melt after trapping when the diamond was at higher T. Next on the way up during the T and P decrease the melt should again crystallize to form the phases detected in the inclusions by means of the electron microprobe analysis. To check on this model of inclusion formation, a calculation of the bulk composition has been made to obtain the possible mineral composition of the hypothetical aggregate. Two possibilities exist: 1) either the melt formed by complete melting of an aggregate of seven phases: omphacite + phlogopite + sanidine + sphene + kyanite + coesite + Fe_nO_m;

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[1] After submitting the present paper for publication, a paper has been published by Bakumenko, I.T. [20], where this author, on the basis of numerous data on melt inclusions, suggests a connection between andesite magmas and the melting of mantle coesite eclogites.

or 2) omphacite + sanidine + pyrope-almandine + sphene + rutile + coesite + Fe_nO_m. The compositions of minerals typical of the rutile eclogites were taken for calculations. Sphene has been included because after calculation of the essential phases, an excess of CaO, TiO_2 and SiO_2 remained. The low probability of the existence of such a multimineral association and its trapping by diamond [to form the] aggregate is obvious. For this reason the epigenetic formation of this melt inclusion is not probable, and its syngenetic formaiton with the diamond should be accepted.

Evaluation of the temperature and pressure evolution during diamond growth. Occurrence of the mineral pairs garnet-omphacite in various growth zones yields the possibility of evaluation of P and T for these growth zones. Qualitative evaluation of the P evolution may be performed by use of two independent geobarometers: dissolution of Eskola's Ca-molecule ($Ca_{0.5}AlSi_2O_6$) in clinopyroxene [17] and the X_{Ca} value in garnet [18]. Decrease of Eskola's molecule in omphacite inclusions from the center to the margin of the diamond (Fig. 2) and decrease of the X_{Ca} in garnet in this direction (Table 2) prove a P increase during the diamond crystallization.

Evaluation of the P-T-evolution has been performed by use of the Ellis-Green geothermometer [19] by solution of the direct and reverse problem. Temperatures for the respective mineral pairs have been calculated for P 50 kbar. Next, supposing an isothermal process, and using the equation from [19], P for the association: garnet-7, omphacite-6, has been calculated. The data obtained (Table 4), evidently indicate extreme changes in either T or P. The real range of the PT evolution was probably smaller than the calculated values.

The omphacite composition inversion shown in Fig. 2 does not exclude even more complicated T evolution. One may propose, on the basis of the data obtained, two alternative viewpoints on the evolution of the PT parameters of diamond formation: 1) diamond crystallization occurred during P increase and T decrease. Thus the melt inclusion may be considered as a portion of the remnant melt. It is possible that the next stage of the diamond growth was already in the subsolidus area; 2) diamond crystallized under conditions of high P and T. One may suppose that during the trapping of the omphacite-5 inclusion by the diamond in the intermediate area, T was >1250°C. Next the inversion in evolution of P and T could occur. In this case the melt inclusion would be a portion of the primary melt formed from rutile eclogites. The whole stage of the further diamond crystal growth thus should be in the sub-liquidus area. Whether such inversion could be connected with the melt accumulation with its inevitable segregation from the solid remnant or for another reason is still unknown.

Table 4. Temperature and pressure evolution during crystallization of diamond No. 1168

Growth zone in the diamond	X^{Gar}_{Ca}	$K^{Gar/Cpx}_{D\ Fe/Mg}$	T, °C (P 50 kbar)	P, kbar (T 1250°C)
Central, garnet-4/omphacite-3	0.255	2.60	1250	50
Peripheral garnet-7/omphacite-6	0.144	2.31	1190	64

Conclusion

1. For the first time partly crystallized melt inclusions have been found in a diamond crystal from the eclogite paragenesis. This inclusion bears admixtures of sulfur, phosphorus, chlorine and, possibly, other volatiles. Calculated bulk composition of this inclusion is similar to Ti-rich hypersthene andesite.

2. The melt inclusion, seemingly, is a portion of the primary melt of the rutile eclogites.

3. Studies of the zonally distributed inclusions of omphacite and garnets gave a quantitative evaluation of PT conditions in the growth process of the given diamond crystal. Diamond crystallization occurred during P increase. T evolution in the diamond growth process has more uniform character.

References

1. Sobolev, N.V. Deep-seated inclusions in kimberlites and the problem of the upper mantle composition: Novosibirsk, 1974, 263 pp.
2. Harris, J.W., Gurney, I.I. The properties of diamond: London, Academic Press, 1979, 555 pp.
3. Meyer, H.O.A. International Gemmological Symposium Proceedings, Los Angeles: Gemolog. Inst. Amer., 1982, 142 pp.
4. Bulanova, G.P., Varshavskiy, A.V., Leskova, N.V., Nikishova, L.V. Physical properties and mineralogy of diamond: Yakutsk 1986.
5. Bulanova, G.P., Keskova, N.V., Pavlova, L.A. Physical properties and mineralogy of natural diamond: Yakutsk, 1986.
6. Forbes, W.S., Flower, M.F.: Earth and Planet. Sci. Lett. 1974, v. 22, p. 60.
7. Edgar, A.D., Green, D.H., Hibberson, W.O.S.: Petrol. 1976, v. 12.339.
8. Ryabchikov, I.D., Boettcher, A.L.: Izv. AN. SSSR, Ser. Geol. 1980, no. 3.
9. Prinz, M., Manson, D.V., Hlava, P.F., Keil, K.: Phys. and Chem. Earth, 1975, v. 9, p. 797.
10. Bulanova, G.P., Argunov, K.P.: Doklady AN SSSR, 1985, v. 284, no. 4, p. 953.
11. Pavlenko, A.S., Tarasov, L.S., Shevalevskiy, I.D., Ivanov, A.V.: Lunar soil from the Sea of Izobiliya, Moscow, Nauka
12. Roedder, E. Evolution of the igneous rocks. Development of ideas during 50 years: Moscow, Mir, 1983, p. 14 [15-57].
13. Green, D.H., Pearson, N.J.: Chem. Geol. 1986, v. 54, p. 185.
14. Sobolev, V.S., Sobolev, N.V.: Dokl. AN SSSR, 1975, v. 221, no. 2, p. 435.
15. Green, D.H., Ringwood, A.S.: Earth and Planet. Sci. Lett., 1966, v. 1, p. 307.
16. Zharikov, V.A., Ishbulatov, R.A., Litvin, Yu.A. Problems of petrology of the Earth's crust and upper mantle. Nauka, 1978, 8 pp.
17. Zharikov, V.A., Ishbulatov, R.A., Chudinovskikh, L.T.: Geologiya i Geofizika, 1984, no. 12, p. 54.
18. Brey, G.P., Nikel, K.G., Kogarko, L.: Contr. Mineral. and Petrol. 1986, v. 92, p. 448.
19. Ellis, D.J., Green, D.H.: Contrib. Mineral. and Petrol. 1979, v. 71, p. 13.
20. Bakumenko, I.T.: Geologiya i Geofizika, 1986, no. 7, p. 125.

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Received by the redaction
24.VII.1986

GRISHINA, S.N., DUBESSY, J., KONTOROVICH, A.E. and KUDRINA, T.R., 1987, Inclusions in Cambrian salts of Bakhtinsky megaprojection as indicator of conditions of oil and gas pool formation and conservation: Geology & Geophysics (Novosibirsk), no. 12, p. 31-38 (in Russian; translation courtesy of Dr. Svetlana Grishina*).

INTRODUCTION

One of the key moments in the history of petroleum accumulation in the Lena-Tunguska province was the epoch of Triassic magmatism dated by the end of Permian or beginning of Triassic [4,10]. It was accompanied by deep contact transformations of sedimentary rocks with organic matter and oil scattered in them, a number of important regularities of oil and gas distribution being affected. Many aspects of the effects of trap magmatism on the oil- and gas-bearing characteristics, however, are not investigated sufficiently [6].

In the present work, the Cambrian deposits of the Bakhtinsky megaprojection estimated as promising ones for oil and gas prospecting were chosen as a subject of research [4]. This region is characterized by numerous trap intrusions, their fraction of total rock thickness being up to 40%. The distribution of oil and natural gases is also rather specific for this region. The Bakhtinsky megaprojection is the first region on the Siberian platform where pools of free carbon dioxide gas have been revealed. They are found in the top of the Kostinskaya suite on the Nizhnetungusskaya and Tanachinskaya areas. Carbon dioxide, methane, nitrogen amount to 86 vol.%, 2 vol.% and 1-2 vol.% each, respectively.

To understand the nature of gas pools it was interesting to study relicts of the fossil fluids that migrated into permeable rocks in the epoch of trap magmatism, the composition of which was undoubtedly determined by interaction in the system: magma-initial rock-forming minerals- water(s) - and the initial liquid and gaseous hydrocarbons. This will give also a good opportunity to study the fluid associated with the thermal metamorphism of dolomite and evaporites. In this connection fluid and solid inclusions in salts have been studied in the region. Some salt samples taken in deep wells on the Nizhnetungusskaya, Kochumdekskaya and Bakhtinskaya areas have been chosen for investigation.

GEOLOGICAL SETTLING

The most detailed investigation has been carried out on the samples from the 4th well of the Nizhnetungusskaya area which were taken 30 m apart from the contact of dolerites and saliniferous dolomites with the salt interlayers of the upper subsuite of the Belskaya suite of Cambrian (Kostinskaya suite, the middle part) (Fig. 1). The well is on the right bank of the Deltula river in the north-western Bakhtinsky megaprojection. It crosscuts Devonian, Silurian, Ordovician and Cambrian sediments. This sedimentary pile reserve is intruded by dolerites to various extents.

The thickness of the upper subsuite of the Belskaya suite on the Bakhtinsky megaprojection varies from 120 to 135 m. The suite is characterized by the alteration of saliniferous dolomites and salts (mainly NaCl). Their ratio in various wells is not the same [8]. Dolomites are saliniferous, light grey, finely and microcrystalline, with interlayers of anhydrites and sulphate-bearing dolomites with thickness up to 2 m. There are numerous inclusions of pyrite. Dolomites from the surface are often

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*Ed. note: Dr. Grishina has revised the text (and literature citations), and has added some new data that are not in the original printed version. Translation of tables and references by A.K.

Fig. 1. Schematic location of areas: 1 - Nizhnetungusskaya, 2 - Tananinskaya, 3 - Kochumdekskaya, 4 - Bakhtinskaya

cavernous due to salt leaching. The salt layers reach a thickness of 2 to 10 m. The presence of microinclusions of anthraxolite in pores is indicative of oil in the Bakhtinsky megaprojection deposits [that have undergone] trap intrusions [4].

The nearest intrusion (44 m thick) is 22.6 m below the interval under study. In the upper part of the section four intrusions of 52, 64, 12 and 945 m thickness are found 689, 1412, 1419 and 1961 meters, respectively, above the sampling place (Fig. 2). The intrusions penetrated by the well belong to a normal series of dolerites which is close to the Katanga type and stands out only due to somewhat increased concentrations of Mg and Fe. Localization and distance of samples from a dolerite intrusion are given in Table 1.

EXPERIMENTAL PROCEDURE

All the samples were studied microscopically. Double-polished plates were used to describe the disposition, character, abundance and morphology of the inclusions. Cleavage plates of 300-400 μm thick were used to study individual inclusions. The techniques were as follows: homogenization, freezing, micro-Raman spectroscopy and gas chromatography. The inclusion homogenization was carried out in a heating stage as designed by Dolgov and Bazarov [5]. The temperature measurement accuracy is respectively ± 4-5°C and ± 6-9°C for temperature ranges 100-150°C and 150-300°C [12]. Freezing was carried out using Bazarov's design equipment [1]. The phase transition temperature determination error is ± 0.5°C near the melting point of CO_2 (-56.6°C). Inclusion composition was studied on the MOLE-type Raman spectrometer designed by Delhaye and Dhamelincourt I4(Jobin Yvon) in the Centre de Rècherches sur la Geologie de l'Uranium (CREGU, France). The bulk gas composition from halite samples was determined on an improved chromatographic set-up which consists of two chromatographs JIXM-80 and JIXM-8MII7.

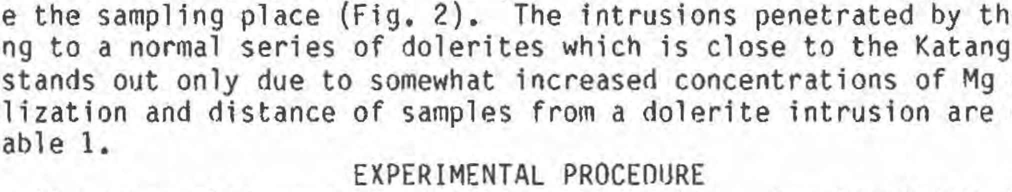

Fig. 2. Geologic section of Verkhnebelskaya subsuite (Cambrian) in Nizhnetungusskaya well No. 4: 1 - salt-saturated dolomites, 2 - salt, 3 - sulphate-bearing dolomites, 4 - dolerites, 5 - sampling horizons

DESCRIPTION OF FLUID INCLUSIONS OF NIZHNETUNGUSSKAYA-4 WELL

Four types of sulphur and carbon dioxide inclusions, differing in morphology, have been found by microscopic study. They are found in each of the samples studied (Nos. 1,2,3,4) except one (No. 5). Brine inclusions have been found in sample No. 5, whereas non-aqueous phases were observed by optical microscope in any [all?] types of inclusions of the first four samples. The distribution of sulphur-carbon dioxide inclusions is the same in samples 1-4 and is characterized by irregularity. There are zones completely free of inclusions, single inclusions and groups of uniform inclusions or inclusions of different types in the same crystal. The total number of inclusions is not great and rarely exceeds 20-25 per 1 cm^2 of the surface under study. One of the signs of "primary character" of the inclusions is their irregular distribution in the crystal rather than their association with healed fractures. The "primary character" is to be understood in this case in the sense of synchronization of their formation and salt recrystallization rather than in the sense of their sedimentary character.

1. Sulphur solid inclusions without carbon dioxide impurity have been found in halite grains in the form of bipyramidal crystals no less than 30 μm in size (Fig. 3a). It is one of the rarest types of inclusions.

2. Essentially carbon dioxide inclusions without solid phases. They are liquid one-phase inclusions under room temperature. Their shape is globular or close to the shape of a negative crystal of halite but with rounded corners. Their size varies from a few μm to 200 μm. This type of inclusion is the most common and amounts to nearly 50% of the inclusions under study in total. The freezing study revealed a high density. Homogenization occurs into the liquid phase at low temperatures, between -18°C and -23°C, which was not earlier observed in halite samples. The CO_2-inclusions trapped together with solid phases, whatever their type (solid salt inclusions or anhydrite), have a higher Th CO_2 = (-12, -10, -7, +9)°C. The melting of solid carbon dioxide occurs in the temperature range -57 to -58°C, indicating the presence of additional components. Under cooling the formation of another solid phase has also been observed after the solidification of carbon dioxide. It melts between -101 and -102°C. From the inclusion composition indicated by the Raman spectrometry (Table 2) this phase is believed to be solid hydrogen sulphide.

3. Carbon dioxide inclusions with crystalline or amorphous sulphur. Nearly one third of the carbon dioxide inclusions contain crystalline or amorphous sulphur. Sulphur crystals in inclusions are isometrically bipyramidal and, predominantly, of elongated habit. The size of sulphur crystals is of some micrometers to 20-30 μm. One sulphur crystal of 80 μm in size was found in a 350-μm carbon dioxide inclusion. The sulphur-to-carbon dioxide volume ratio varies from one inclusion to another. The bipyramidal sulphur crystals occupy a volume of 0.1 to 1% (Fig. 3d). Crystalline sulphur of irregular form occupies a larger volume in inclusions (up to 25 vol.%).

Amorphous sulphur in inclusions is in the form of globules with a bright glassy surface (Fig. 3f). Inclusions commonly have one or two globules, but as an exception, as many as 15 globules may occur in one inclusion. Amorphous sulphur appears similar to gas bubbles but when considered in detail the globules prove to be attached to the walls of the vacuoles. The volume ratios also differ, sulphur being 0.1 to 1% of the volume.

When heating, crystalline sulphur goes into the liquid state, with a perfect spherical drop being formed, and then gradually dissolves in carbon dioxide. The dissolution temperature depends on the volumetric ratio of

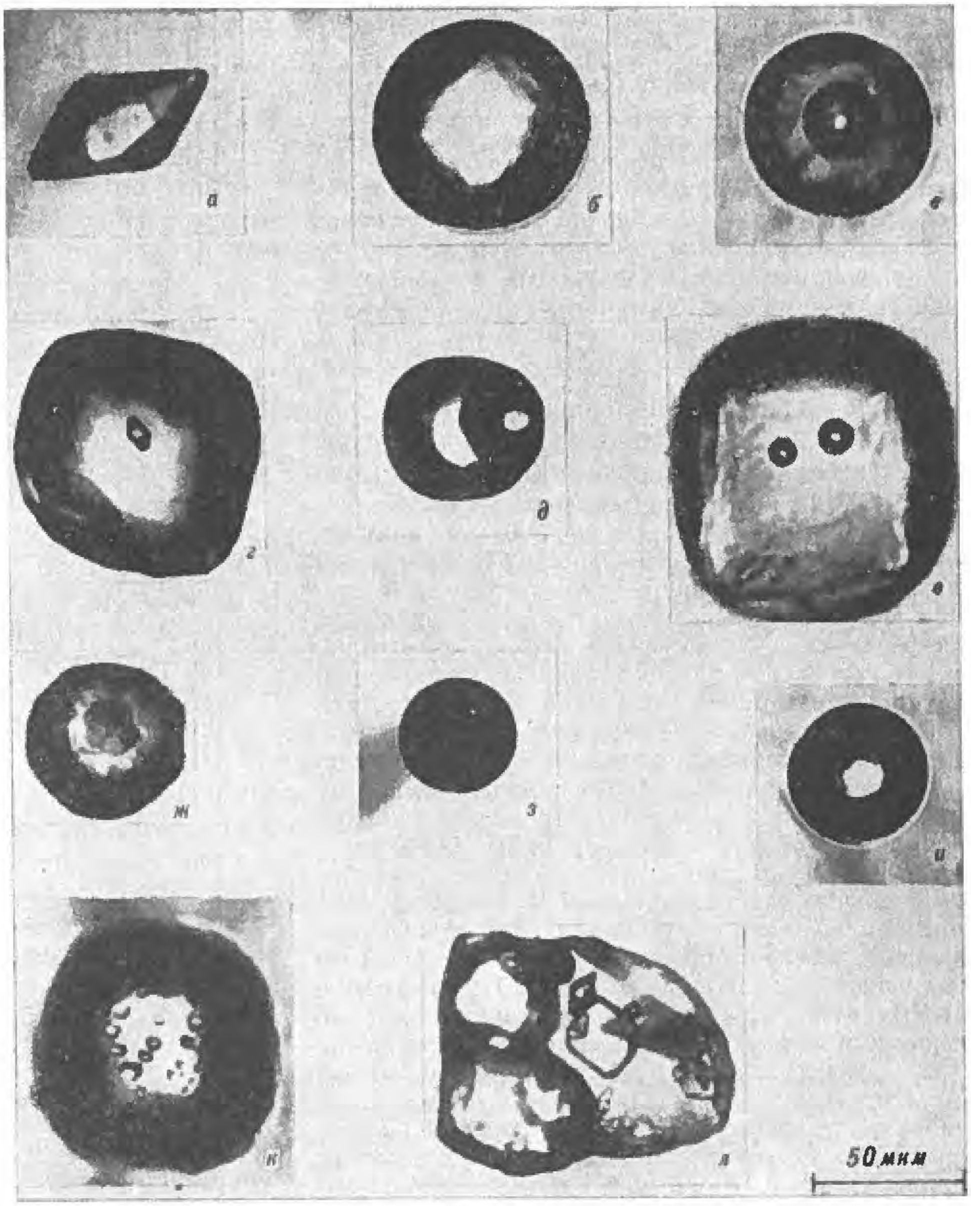

Fig. 3. Morphology of carbon dioxide and sulphur inclusions: a - bipyramidal sulphur crystal (Scr) in halite; b,c - essentially CO_2 inclusions at temperatures 25 and -30°C, respectively; d - CO_2 inclusion with crystalline sulphur; e - CO_2 inclusion with crystalline sulphur (Scr) of irregular shape; f,g - CO_2 inclusions with amorphous sulphur; h - spherical inclusion of crystalline sulphur with small amounts of liquid CO_2; i - spherical inclusions of amorphous sulphur with a droplet of liquid CO_2; k - sulphur inclusions containing some cavities with liquid CO_2; l - crystalline sulphur in water-carbon dioxide inclusion. Samples: g - Kochumdekskaya, l - Bakhtinskaya; the rest from Nizhnetungusskaya.

sulphur and carbon dioxide and ranges from 110 to 350°C. In inclusions where the sulphur volume exceeds roughly 20-30%, dissolution is observed only up to a certain degree, and complete dissolution of the S_8 never occurs even with temperature increase. On return to room temperature, a globule of amorphous sulphur appears instead of a crystalline one.

The freezing study of inclusions with amorphous or crystalline sulphur has shown the same temperatures of phase transitions as CO_2 inclusions without solid phases. The inclusion composition determined by Raman spectroscopy also does not differ from the inclusion composition without solid phase (Table 2).

4. Sulphur dominant inclusions with carbon dioxide occur in two varieties:

a) Opaque spheres which contain very small irregular crystals of sulphur and carbon dioxide (Fig. 3h);

b) Spherical inclusions of amorphous sulphur with a bubble of liquid carbon dioxide attached to the inclusion wall (Fig. 3i).

The inclusions of the types 4a and 4b are reversible by heating and cooling. Their sizes ranges from 20 to 40 μm, and they constitute less than 10% of all types of inclusions.

On heating a type 4a inclusion up to the melting point of sulphur, a bubble of liquid carbon dioxide[sic; sulfur meant?] forms; on cooling down to room temperature, the sulphur transforms into an amorphous state and the type 4a inclusion takes the form of type 4b.

The bubble of liquid carbon dioxide in an inclusion that is primarily of type 4b or was transformed after heating into type 4b dissolves at a temperature of 60-70°C, i.e., below the melting point of sulphur. If the inclusion is heated further, to the sulphur melting point and then is cooled down to room temperature, the type 4b inclusion transforms into type 4a.

The freezing study of carbon dioxide bubbles in 4a and 4b inclusions has revealed the same melting temperature of solid carbon dioxide as in carbon-dioxide inclusions but a much higher temperature of homogenization to the liquid phase (+10 to +16°C).

c) Cubic inclusions of sulphur crystals with smoothed corners and a carbon-dioxide bubble in one of its corners

Tm CO_2 = -57.5°C, Th CO_2 (in L) = -3, -4°C.

d) Isometric sulphur inclusions containing one or more cavities with carbon dioxide (Fig. 3k)

Tm CO_2 = -57°C, Th CO_2 (in L) = -8, +15°C.

No evidence of water or other aqueous dominant primary inclusions was found in samples Nos. 1 to 4. The secondary single-phase water and gas-water inclusions with various degrees of filling are clearly related to later processes. Crushing of these inclusions in liquid has shown that their pressure is close to atmospheric.

5. Aqueous inclusions. Metastable inclusions of brines have been found in sample No. 5, the one nearest to the intrusion (26.6 m). Carbon dioxide and sulphur inclusions have not been found there. The brine inclusions have sizes of several μm to 70 μm.

Morphologically, this type of inclusion is represented by two irreversible modifications: single-phase water inclusions and three-phase inclusions with a gas bubble and a birefringent solid phase. On heating to near 30°C the gas bubble and solid phase dissolve simultaneously without recovering after being cooled to room temperature. On cooling single-phase inclusions to -60 or -70°C a solid phase and gas bubble are formed, which do not disappear when heating to room temperature and dissolve only at 30°C like the initial three-phase inclusions. The experiments described indicate that the bubble is a result of shrinkage rather than of cracking of inclusions. The daughter solid phase formed simultaneously indicates the supersaturated state of solution.

INCLUSIONS FROM OTHER WELLS

Native sulphur has been found also in the samples of the Kochumdekskaya and Bakhtinskaya wells, but the frequency of occurrence of sulphur inclusions is much lower as compared with the Nizhnetungusskaya-4 well. Sulphur inclusions which appear in the last two samples only as single types are different in shape. There are only globules of amorphous sulphur inside carbon dioxide inclusions (Fig. 3g) in the Kochumdekskaya well samples and faceted crystals of bipyramidal sulphur inside water-CO_2 inclusions in halite of the Bakhtinskaya well (Fig. 31).

Amorphous sulphur in the CO_2 inclusions of the Kochumdekskaya well occurs very rarely, being observed in less than 1% of carbon dioxide inclusions. The CO_2-to-sulphur ratio is constant, with sulphur occupying nearly 0.1 vol.%. Three attempts were made to heat these inclusions up to the homogenization temperature, but all the inclusions decrepitated on heating. The composition of carbon dioxide inclusions and native sulphur were also determined by Raman spectrometry (Table 2).

None of the above inclusion types were found in the Tanachinskaya well samples taken on the boundary of the zone of thermal effect of the intrusion. However, the halite is clearly recrystallized, without relicts of water inclusions of sedimentary or diagenetic origin. The only type of fluid inclusions is small bubbles of gas on the surface of solid inclusions of anhydrite and dolomite. As the inclusion sizes do not permit methods of individual inclusion study to be applied, their bulk composition was studied by gas chromatography. Samples were heated at 400 and 700°C to collect the gases from the samples (Table 3).

CONCLUSIONS

The source of elementary sulphur, carbon dioxide, and hydrogen sulphide in inclusions, hydrogen sulphide in waters, free carbon dioxide and in water solution seem to result from the thermal effect in oil-saturated dolomites and sulphate-bearing rocks.

Dolomites affected by elevated temperatures are known to give rise to secondary calcites with carbon dioxide loss [11]. In the presence of clay admixture in the rocks, dolomites transform, with mixed layer minerals being formed. The transformation of sulphate rocks in the presence of oil as a reducer and at temperatures 100-150°C is followed by formation of hydrogen sulphide and elementary sulphur [2,9,13].

It is reasonable to conclude that carbon dioxide, sulphur and hydrogen sulphide in gas-liquid inclusions are paragenetically related to carbon dioxide gas pools on the Nizhnetungusskaya and Tanachinskaya areas as well as to occurrences of water-dissolved hydrogen sulphide.

On this basis, the formation time of the investigated inclusions as well as that of carbon dioxide pools can be dated as of the epoch of intensive trap magmatism, i.e., as it was noted earlier, by the end of Permian or the beginning of Triassic.

Ed. note: Translations of the Tables and References unfortunately were not received in time; they will appear in the Errata of Volume 22.

SAMOILOV, V.S., KOVALENKO, V.I., NAUMOV, V.B., SANDIMIROVA, G.P. and CHUVASHOVA, L.A., 1988, Immiscibility of silicate and salt melts during the formation of the Mushugaĭ-Huduk alkaline complex (southern Mongolia): Geokhimiya, no. 10, 1988, p. 1447-1459 (in Russian; translation by D.A. Brown).

Carbonatite and apatite streaky segregations which are syngenetic with the enclosing igneous silicate rocks have been observed in melanephelenites, trachytes and porphyritic syenites of the late Mesozoic igneous complex Mushugaĭ-Khuduk, southern Mongolia. The segregations of carbonatites were formed in the process of crystallization of high-T (~1200°) salt melt enriched in Ca and F. The segregations of apatite rocks were formed in the process of crystallization of the high-T phosphate-sulfate salt melt enriched in REE. A conclusion has been made that immiscibility of silicate and salt melts played

an important role in the process of formation of rocks of the ore-bearing Mushugai-Khuduk igneous complex. (Authors' abstract)

Geological, petrological, and geochemical studies of various associations of carbonatites and apatite rocks with alkaline magmatic rocks, and also experimental modelling of carbonate and phosphate systems, clearly indicate the occurrence of immiscibility between silicate and salt melts under specified conditions [1-6]. During detailed studies of the Mashugaĭ-Huduk Complex in southern Mongolia [1], spheroidal streak-like carbonatite and apatite segregations have been discovered amongst the magmatic rocks. The minerals of these segregations (fluorite and apatite) exhibit signs of crystallization from salt melts of extremely specific composition at T close to those of the minerals enclosing segregations of silicate magmatic rocks. It may be suggested that during the formation of the ore-bearing carbonatite and apatite rare-metal rocks that make up individual geological bodies, immiscibility of the silicate and salt melts was of prime importance. The present paper is devoted to a petrographic and geochemical description of these carbonatite and apatite segregations. (Abstract by D.A. Brown)

A GENERAL DESCRIPTION OF THE MUSHUGAĬ-HUDUK COMPLEX

We have given a detailed description of the geological position of the Mushugai-Huduk Complex in [1]. It is made up of Upper Jurassic alkaline and subalkaline volcanic, subvolcanic, and intrusive rocks, mainly of intermediate composition with a potassic trend, and various ore-bearing rocks, including carbonatites and apatite-enriched varieties. The principal role amongst all these rocks is played by flows of subalkaline leucotrachytes and subvolcanic trachytic bodies, with less common melanocratic alkaline volcanics of melanephelinite-melaleucitite composition, and volcanic and subvolcanic bodies of trachydacite and trachyrhyodacite. Amongst the intrusive rocks, there is a predominance of syenites and syenite-porphyries (including nepheline and quartzose forms). Accompanying the various syenites, there are rare melanocratic syenites and shonkinites which form small stocks and dikes.

The alkaline magmatism has been spatially and genetically associated with the formation of the ore-bearing rocks of the complex, which consist of mineralized breccias with a carbonatite matrix, rocks of the carbonatite series, and those enriched in apatite. Amongst the rocks of the carbonatite series (Table 1) in approximately equal amounts, there are carbonatites [p. 1448] and varieties in which the carbonate is subordinate to fluorite and silica minerals (quartz and chalcedony). Amongst the carbonatites themselves, there is a marked predominance of calcitic varieties, containing (in variable amounts) fluorite, quartz (chalcedony), barite, celestite, bastnesite, dolomite (ankerite), galena, anglesite, and wulfenite. Dolomitic carbonatites are rare within the complex. The carbonatites of the complex are enriched in Sr, Ba, Pb, and rare earths, and are depleted in Nb, which is typical of carbonatites associated with magmatic potassic rocks [2].

Amongst the apatite-enriched rocks (Table 2), there are: a) veined magnetite-apatite ores and products of their hydrothermal alteration (magnetite-fluorite-celestite-apatite ores), and b) clearly conjugate feldspar-apatite, phlogopite-apatite, and apatite rocks. Essentially apatite rocks form a steeply-dipping lode in the contact zone of one of the syenite-porphyry stocks. An important geochemical peculiarity of all the varieties of apatite-bearing rocks in the complex, as with the carbonatites, is enrichment in rare earths, Sr, and Ba [1].

The relationships between all the rocks in the complex listed is given in the composite stratigraphic column in publication [1].

Компонент	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	4,80	0,97	12,00	14.49	6.80	27.50	44.66	7.09	14.20	10,15	23.48	20.21
TiO_2	0.04	0.05	0,03	0.20	0,16	0.22	0.42	0.04	0,05	0.09	0,06	0.08
Al_2O_3	1,65	0.23	5,00	4.28	2.00	7,78	13.94	0.74	2.40	2.27	0.65	[illegible]
Fe_2O_3	0,70	0,32	1.57	3,63	3.26	3.39	2.91	5.68	1,81	2.98	1.34	1.05
FeO	0,11	Не обн.	0.09	0.81	0.59	1,02	2.10	0.50	0,94	0.59	1.25	0.84
MnO	0,13	0,10	0.11	0.18	0.17	0.18	0.15	0,41	1,17	0.47	0,57	0.48
MgO	0.90	0.22	1,94	2,12	1,69	2,17	3.21	0.22	1,73	1,25	0,76	0.65
CaO	53,42	53.17	47,54	42.72	47,47	31.47	13,94	47,85	36.09	45.02	38.60	40,25
Na_2O	0,30	0.06	1,18	1.23	0,68	2.31	5.93	0,08	0,18	0.45	0.20	0.28
K_2O	0,14	0,07	0,14	0,77	0,62	1.41	1,52	0.25	0,51	0.43	0,46	0.74
P_2O_5	0,02	Не обн.	0,02	0.16	0.14	0.20	0.47	0.17	0.28	0.18	0.58	0.50
CO_2	27,16	41,59	17,02	22.85	29,11	15.30	5.52	31,70	26,66	27.10	17,93	26.84
F	12,58	0,48	16.00	6,42	5.87	4,84	1.43	3.77	3.35	6.53	10.39	3.39
SO_3	0,28	0,30	Не обн.	0,33	0,28	0.42	0.37	0.60	4.68	1,48	1.77	1,32
Sr	9100	12 900	7400	12 460	14 700	9500	5000	4075	37 350	15 000	13 400	6 300
Ba	1760	290	2200	1 720	1 800	4380	4400	6575	8 550	4 660	16 100	16 300
Pb	144	76	235	180	175	125	174	635	300	310	934	429
Zn	36	20	37	60	53	56	63	192	117	102	121	105
Zr	273	—	—	324	—	—	—	98	130	206	267	218
Co	4.0	2,0	2,8	17	14	15	16	7.9	4,2	8.1	13	3.0
Ni	6,5	6.0	8.2	15	8.8	17	23	2,5	2	7	4.7	3.8
Cr	3	3	3	13	3.5	23	31	3	3.5	5	5,1	5.8
V	50	40	21	53	33	59	106	57	24	54	85	68
Cu	5,4	6,0	12	73	70	71	78	6.6	10	23	18	9.8
La	355	330	300	280	310	240	310	1850	670	800	5 870	3 900
Ce	295	310	260	380	400	340	490	2000	760	900	5 380	3 850
Nd	175	180	110	180	235	150	255	485	210	270	1 440	1 130
Yb	1,2	1,5	1,0	2,0	1,8	2.5	4.2	2,8	2,0	2,0	9,8	6.0
Y	40	35	30	42	38	45	37	80	47	53	220	140
n **	4	1	1	5	2	6	7	2	3	14	117	64

Table 1. Chemical Composition of Carbonatite Segregations*

Notes. 1-9) carbonatite segregations: 1-3) in melanephelinite tuffs: 1) average composition, 2) central part, 3) peripheral part; 4-7) in melanephelinites: 4) average composition, 5) central part, 6) peripheral part, 7) outer silicate zone; 8) in trachytes, 9) in syenite-porphyries; 10-12) average composition: 10) of carbonatite segregations, 11) of rocks of carbonatite series, 12) of carbonatites.

+ Component
++ Not found
* Petrogenic components in wt %, remainder in ppm.
** Here and in Tables 2 and 4, number of samples in averages.

SEGREGATIONS OF CARBONATITES AND APATITE IN THE MAGMATIC ROCKS

Carbonatite segregations in melanocratic alkaline volcanics. Alkaline rocks of this kind have been encountered in the northeastern part of the complex, where they make up a small flow with an overall thickness of up to 50 m, [p. 1449] resting homoclinally with marked unconformity on rocks of the Paleozoic basement.

Carbonatite segregations have been identified in the lower portion of a flow of melanocratic alkaline volcanics, in its melanonephelinitic part, and mainly in the middle of the latter. Segregations have been identified in extremely significant amounts (≤5-6 per dm^2 (normally 1-2)). They are oval or circular in shape, very rarely with appended apophyses; they vary in size from 1-2 mm up to 3 cm across, and for the most part are 0.5-1.5 cm. Fine (up to 1 mm) veinlets of a fluorite-calcite carbonatite have been noted cross-cutting the segregations and the surrounding melanephelinites. The boundaries of the segregations are ubiquitously distinct. The small globule-like segregations and some of the large ones are marked by sharp contacts with the melanephelinite. In this instance, the small globules may be surrounded by thin cryptocrystalline brownish rims, and in the case of the large segregations, we have noted the inward growth of the pyroxene crystals of the melanephelinites, and less frequently, of nepheline and mica. In addition, the large segregations are often separated from the melanephelinites by greenish-gray zones, 0.2-0.5 cm thick, made up mainly of fine-grained aggregates of alkali-feldspar and pyroxene, which are associated with fine-grained calcite (4-25%), fluorite, biotite, nepheline, and sometimes garnet.

The carbonatite segregations in the melanephelinites consist of calcite (40-85%), fluorite (5-25%), alkali-feldspar (10-40%), pyroxene (2-15%), and phlogopite (1-6%). Carbonate makes [p. 1450] up not less than 50% of the volume of the segregations, but its role markedly diminishes in their outer parts (down to 20-30%), whereas the cores of the segregations may be almost

Компонент†		2	3	4	5	6	7
SiO_2	—	4,72	10,25	26,51	51,20	62.08	61,73
TiO_2	—	0,06	0,14	0.37	0.60	0.70	0.67
Al_2O_3	—	1,65	2,62	5,52	13.55	16,21	[illegible]
Fe_2O_3	—	3.19	3,19	3.91	2,96	2.63	2.52
FeO	—	1.09	2,25	1.41	1,38	1,38	1.14
MnO	—	0,16	0,19	0,12	0.08	0,08	0.07
MgO	—	0.12	0.34	0.56	0,73	0,68	0,77
CaO	47.60	43.08	39.12	27.43	8.86	1.42	1.30
Na_2O	—	0,37	0,46	1,20	2.71	3,75	3,94
K_2O	—	0,27	0.58	2.13	5.86	7.90	7,73
P_2O_5	34.88	31.86	28,63	20,47	6.51	0.32	0,29
F	—	2,99	2,15	1,52	0.55	0,26	0,24
SO_3	—	2,58	1.92	1,01	0.68	0.20*	0,18*
CO_2	—	0.29	0,59	1,63	1.32	1,15	1,08
Sr	—	1.20	1,15	1.12	0.94	0.71	0,73
Ba	—	0,24	0.56	0.50	0,43	0,28	0,30
TR+Y	8.54	7,51	5.65	3.75	0.96	0,089	0.093
ΣCe/ΣY	22.8	22.3	22,1	22,4	21.6	13.2	12.8
δEu	0.50	0.47	0.54	0.56	0.46	0.66	0.64
La **	25.6	26,5	25.9	26.1	26.7	25.3	24.4
Ce	47.2	45.4	45.7	45.8	44.6	41,8	42,5
Pr	5.4	5,5	5.5	5,9	5,5	4.8	5,0
Nd	14,7	15,1	15.6	14.9	15,6	14.8	15,0
Sm	2.6	2,6	2,7	2,8	2.8	2,3	2.2
Eu	0.3	0.3	0,3	0,3	0.3	0,4	0,4
Gd	1.0	1,1	1.0	1.1	1,4	2.4	2.4
Dy	0.5	0,8	0.4	0.5	0.7	1.1	1.0
Ho	0.1	0,1	0,1	0,1	0.1	0.2	0.2
Er	0,2	0,2	0,3	0.2	—	0,3	0,4
Yb	0.2	0,2	0,2	0,2	0.2	0.4	0.4
Y	2,2	2,4	2,3	2,3	2.1	6.2	6.1
n	7	5	6	8	7	2	6

Table 2. Average Chemical Composition of Apatite-Bearing Rocks and Syenite-Porphyries, wt%

Notes. 1) apatite from anchimonomineralic apatite rocks, 2) anchimonomineralic apatite rocks, 3) phlogopite-apatite rocks, 4) feldspar-apatite rocks, 5) syenite-porphyries with apatite streaks, 6) syenitic component of latter, 7) syenite-porphyries, containing no apatite streaks.

+ Component

* Total sulfur.

** Amounts of individual rare-earth elements in percentages with respect to sum of trace elements.

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completely calcitic. Segregations have also been found in which calcite is subordinate to fluorite and feldspar. The calcite in the segregations is medium-grained, gray, and filled with numerous microscopic inclusions of a black ore mineral. Towards the periphery of the segregations, the amount of the latter decreases and the carbonate acquires a light-gray color. The calcitic groundmass seemingly cements idiomorphic crystals of white sodic orthoclase, bright-green aegirine-augite, platelets of light-cinnamon phlogopite, and rounded grains of violet fluorite. However, the fluorite commonly forms thin rims (≤1 mm) around the feldspar and pyroxene crystals. These crystals reach 3-4 mm in length, and the phlogopite platelets are ≤2.5 mm across. The crystals of homogeneous sodic orthoclase, usually in Carlsbad twins, possess a special idiomorphism.

Carbonatite segregations have also been discovered in the lower part of a member of melanephelinite tuffs (brecciated rocks with a fine- to very-grained groundmass of melanephelinite composition, mainly enclosing clasts of melanephelinites, and also Paleozoic rocks, including limestones. These segregations are somewhat more frequent and larger (≤6 cm across, but for the most part 2-3 cm). They are circular or oval in shape. Their contacts with the country rocks are clear and sharp. The tuffs at the contact with the segregations are virtually unaltered. Segregations of this kind consist mainly of pale-violet fluorite and white calcite, and garnet, nepheline, and their alteration products are joined to them in narrow marginal zonelets. On the whole, calcite predominates in the segregations (on average 65%), but the role of fluorite is also high (on average 30%), especially in the peripheral parts where it may constitute ≤80 wt %. At the same time, the central parts of the segregations have an essentially calcitic composition (≤95%).

Results of chemical analysis of the carbonatite segregations in the melanephelinites are shown in Table 2. These segregations are enriched in Ca, CO_2, F, Sr, Ba, and elements of the Fe group, and rare earths in the range of which light lanthanides play a leading role. In accordance with the change in mineral composition during passage from the central to the peripheral parts of the segregations and farther on towards the outer, essentially silicate zone, precipitation of Si, Al, Fe, Mg, alkalies, Ba, and elements of the iron group, and depletion in Ca, volatiles, Sr, and light lanthanides (relatively to the heavy ones and Y), have been identified.

As compared with the segregations in the melanephelinites, those in the melanephelinite tuffs are markedly richer in fluorite and carbonate, and consequently in Ca, F, and CO_2, and poorer in the remaining petrogenic components, Co, Ni, Cr, and Cu, and in part, Sr and Zn (Table 2). The amounts of rare earths, Ba, and Pb are almost identical in them, although attention is drawn to the fact that La predominates over Ce in the segregations from the melanephelinitic pyroclastics, whereas their central, essentially calcitic parts are markedly depleted in Ba and Pb. The amount of alkalies is also diminished in them (on average 0.44%), although they have been accumulated in greater degree in the peripheral parts (1.3%). As in the previous kind of segregations, Na predominates over K ($Na_2O/K_2O = 2.1$).

Carbonatite segregations in syenite-porphyries. In the southeastern part of the Mushugai-Huduk Complex, there is a large eroded paleovolcanic accumulation, during the drilling of which, one of the boreholes exposed a stock of syenite-porphyries that does not crop out at the surface. In the range of the ~30-m interval in the endocontact zone of this stock, widespread development of carbonatite segregations of spheroidal and drop-like shape, has been identified. The quantity of such segregations is considered (≤80 per dm^2), and their dimensions vary from fractions of a millimeter up to 1.5 cm across in the case of the spheroidal inclusions, and up to 1.5 x 4 cm in the case of the drop-like segregations. [P. 1451] The contacts with the surroundng syenite-porphyries are sharp. The segregations are confined to the groundmass of the rocks. Occasionally, feeble recrystallization of the feldspar in the groundmass and growth of the minerals of the segregations into their inner part, have been observed in the contact zone of the segregations.

The segregations in the syenite-porphyries are marked by a coarse-grained fabric and consist of white calcite (50-70%), dolomite-para-ankerite (7-15%), and fluorite (2-20%), with which alkali-feldspar (3-18%), celestite (≤30%), pyrite (0-25%), anglesite, and occasionally quartz are constantly associated. The carbonatite segregations are rich in S, Sr, Ba, REE, Pb, and Zn. Amongst all of the carbonatite segregations examined, they are on average most enriched in Sr, Ba, and S. As compared with the segregations in the melanocratic alkaline volcanics, they are markedly richer in REE and primarily in light lanthanides.

Carbonatite segregations in the trachytes. These have only been identified in two cases. They are circular in shape with sinuous outlines, and measure ≤2 x 3 cm. The contacts with the groundmass of the trachytes are sharp, and not even microscopic alterations in the trachytes have been noted here. The segregations consist of yellowish medium- and coarse-grained calcite (70-80%), which is associated with a light violet fluorite (6-15%) in the form of rounded grains and crystals, barite (≤3%), altered feldspar, quartz, iron hydroxides, anglesite, and wulfenite. Consequently, the principal role in their chemical composition is played by Ca, CO_2, and F. The segregations are also enriched in Ba, Sr, Pb, Zn, V, and rare earths.

Microinclusions of salt melts in fluorite from the calcite-fluorite segregations. The following kinds of inclusions have been found in the fluorite: 1) gaseous, 2) solid, and 3) crystallized salt melts. We must note the absence of both P and S aqueous fluid inclusions, which first, indicates crystallization of the fluorite from a non-hydrous system and second, the absence of late hydrothermal treatment of these rocks. The gaseous inclusions are

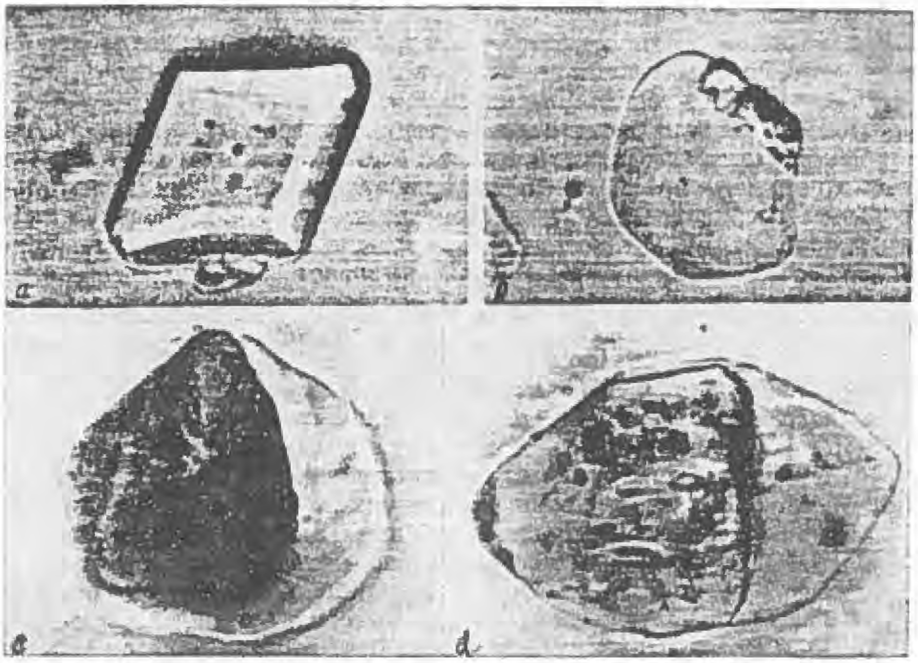

Figure. [p. 1452] Inclusions of salt melts
a, b) inclusions in fluorite, X 1100; c, d) inclusions in apatite, X 900

clearly S, and they are arranged along the cross-cutting cracks. The solid inclusions, judging from the optical properties and microprobe data, consist of pyroxene, phlogopite, apatite, and calcite. Crystallization of these minerals took place prior to or at the time of formation of fluorite. Combined inclusions, consisting of different ratios of inclusions of the second and third kind, have frequently been observed, and especially often, the melt inclusions are combined with calcite and pyroxene.

Inclusions of salt melts are evenly distributed throughout the entire volume of fluorite and are P in origin. They are marked by constant ratios of phases, observed both at room T, and also during thermometric studies. The inclusions (Figure, a and b) consist of 90 wt % of a translucent isotropic mineral, determined by microprobe analysis as hauyne, 5% of carbonate, 4% of a weakly anisotropic mineral (possibly apatite), and a low-density gas phase, as a rule, intensely deformed and poorly distinguishable. About 25 thermometric experiments were carried out, and 10 of them achieved complete homogenization of the inclusions [8]. The first phase changes in all cases began at 600-640°C, when melting of the carbonate was observed and the gas phase acquired a regular spheroidal shape. The second anisotropic phase fused at 950-1120°C. In all of the inclusions, only two phases remained, namely, melt and a gas bubble. The very low viscosity of this melt should be noted, because rapid displacement of the gas bubble within the inclusion (1-2 sec) has often been observed. Complete homogenization with solution of the gas phase in the melt occurs at 1090-1200°C with sufficient time (over several minutes). Even instantaneous (1-2 sec) cooling does not lead to quenching of the melt (it certainly crystallizes).

From the series of photographs, taken during the processes of thermometric studies, a significant increase has been established in the volume of inclusions resulting from fusion of the host-mineral (fluorite). On achieving the homogeneous state, the volume increases threefold as compared with the original state. This has enabled us to calculate the approximate composition and density of the original salt melt, from which the fluorite crystallized (wt %): 39.7 Ca; 35.6 F; 9.3 SiO_2; 7.8 Al_2O_3; 3.4 SO_4; 0.8 P_2O_5; 0.8 CO_2; 2.5 Na_2O; density 3.0 g/cm^3.

Besides P inclusions of an essentially fluoride melt, we have found later inclusions of a carbonate melt in the fluorite. Its T of complete homogenization is 800-920°C. Calculations from photographs of the original and homogenized inclusions have enabled us to identify an increase in volume of 70%, and in the carbonate melt, 22.7 wt % of F has been discovered. The density of such a melt is 2.8 g/cm^3. It may be noted that the lowest Th of an essentially carbonate melt obtained by us for P inclusions in fluorite from stockwork carbonatites of this complex is 600°C. Lower-T (560-360°C) P-S inclusions in this same fluorite are markedly enriched in water, that is, aqueous brines have already been the mineralizing medium.

Segregations of apatite in porphyritic syenites. In the eastern part of the Mushugai-Huduk Complex, apatite rocks, anomalously rich in rare earths were found some time ago [1]. These rocks make up a steeply-dipping stock-like body, up to 50 m thick, confined to the footwall contact of a small massif of porphyritic syenites ('syenite-porphyries') with Paleozoic rhyolites. Apatite, phlogopite-apatite, and feldspar-apatite rocks have been involved in the construction of the body, and the last-named ubiquitously make up the outer endocontact portions of the body (thickness $\leq$15 m). In the zone of contact with the body of apatite-bearing rocks (thickness $\leq$8 m), the syenites contain numerous apatite streaks, measuring $\leq$2-30 cm across, which make up $\leq$40 wt % of this zone of syenites. The number of apatite streaks and their dimensions in the syenites increase towards the contact with the body of apatite rocks.

[P. 1453] The syenites enclosing the apatite streaks are virtually equivalent in mineral and chemical composition to the syenites that do not contain such streaks (Table 2), and do not display any traces of accumulation of apatite and consequently, none of the Ca, F, S, REE, and Sr involved in its composition. The contacts between the syenites and the streaks are sharp, and in the near-contact sectors, no alterations have been identified either in the syenite-porphyries, or in the apatite segregations. The apatite streaks have been formed by a cryptocrystalline honey-yellow apatite, which may be accompanied in insignificant amounts (< 3%) a cinnamon-colored apatite, and also a xenomorphic fine- and medium-grained biotite-feldspar aggregate (< 5%), the mineral equivalent of the groundmass of the syenite-porphyries.

The mineral and chemical composition of the apatite streaks has been determined from the ratio of phosphate and silicate components in them, with the latter in its textural peculiarities and material composition being equivalent to the groundmass of the syenites (Table 2). Their successive enrichment in apatite has been accompanied by the deposition of Ca, P, F, S, Sr, and REE, and depletion in Si, Al, Ti, Mg, and alkalies. The increase in the role of the syenite component is conjugate with some accumulation of Fe and Ba, but their maximum concentration matches that of the phlogopite-apatite rocks and has been controlled by the composition of their component mica, whereas the apatite has been depleted in Ba. The apatite in the streaks and in the stockwork body is a rare-earth variety (on average, we have identified 8.54% TR + Y, with $\Sigma Ce/\Sigma Y$ = 22.8 and δEu = 0.5), and has been enriched in F, SiO_2, sulfate S, and Al_2O_3.

Microinclusions of salt melts in apatite. The inclusions of salt melts in apatite are extremely large, from 20 to 170 μm, most commonly having dimensions of 50-100 μm. They consist mainly of two crystals (Figure, c, d), distinctly different under the microscope, which have been determined by microprobe (Table 3) as apatite and anhydrite. The apatite in the inclusions, which inherits the optical orientation of the host-mineral, is sometimes

1. Компонент	2. Ангидрит		3. Апатит			4. Пироксен	
	1 (9)	2 (9)	3 (17)	4 (14)	5 (32)	6 (1)	7 (3)
CaO	43,86	43.40	50,06	53.74	52,62	21,52	24,39
P_2O_5	0,72	0.71	36,50	39.52	37,61	1,35	0,60
Ce_2O_3	0,08	0,05	3.39	1,56	1.47	0,13	0,08
La_2O_3	0,01	0,02	1,37	0,62	0,74	0,01	0,02
F	—	—	2.92	—	2.16	—	—
SO_3	54,20	51,96	1.39	0.85	0,97	0,00	0,03
SrO	1,02	1.83	0.37	0,51	0.37	0,00	—
BaO	0,04	0,06	0,02	0,00	0,03	0,04	0,00
SiO_2	0,11	0.13	2.35	0,89	1,04	50,97	52.26
TiO_2	—	—	—	—	—	1,10	—
Al_2O_3	0,03	0,04	0,02	0,00	0,04	0,55	0,30
FeO	0,00	0,01	0,02	0,02	0,01	6,58	4.74
MnO	0,01	0,00	0,08	0,04	0,05	0,59	0,59
MgO	0,03	0,06	0,04	0,02	0,05	12,82	15.37
Na_2O	0,00	0.07	0.46	0,48	0,39	0,67	0.47
K_2O	—	—	—	—	—	0,01	—

Table 3. Chemical Composition of Minerals in Microinclusions in Apatite, wt %

Key: 1. Component; 2. Anhydrite; 3. Apatite; 4. Pyroxene

Notes: The number of determinations are shown in parentheses. A dash indicates that the component has not been determined; 1,2) anhydrite in inclusions (1 - sample from surface, 2 - sample from depth of 102 m), 3 - apatite in inclusions, 4,5) apatite-host (4 - sample from surface, 5 - sample from depth of 102 m), 6,7) inclusions of pyroxene in apatite-host.

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clearly zoned (more than 20 zones have been observed over distances of 25 μm), which has been controlled by a change in its composition during crystallization under closed conditions after isolation of the vacuole. A typical peculiarity of the inclusions is the absence of a separately segregated gas phase, and only in the anhydrite are very small (usually < 2 μm) fluid inclusions observed, rarely reaching 5 μm. Moreover, crystals of an ore phase (iron oxides) and carbonates, occupying, along with the fluid phase, not more than 1-3% of the volume of the entire inclusion, are encountered in the anhydrite. Besides the described inclusions, solid inclusions of a greenish pyroxene (Table 3) have been observed in the apatite crystals, and also occasionally, combined inclusions in which pyroxene crystals in varying numbers are present, in addition to apatite and anhydrite.

The thermometric studies, carried out with visual observation, indicate high Tcs for apatite. The commencement of fusion has been identified at only 1130-1150°C, and in the inclusions, a gas bubble appears which is homogenized into the salt melt at 1240-1290°C. Quenching over 2-3 sec certainly leads to crystallization of the melt. In some cases, attempts at homogenization-heterogenization of a single inclusion have been made more than 10 times, which on the basis of rapid displacement of the gas bubble, has established the extraordinarily low viscosity of the salt melt. The high Ths agree well with the high Tms of the main components of the melt (apatite - 1648°C, and anhydrite - 1460°C) and the low water concentration in the melt, according to our calculations not exceeding 0.2 wt %.

Calculation of the ratio of the volumes, occupied by apatite and anhydrite in the inclusions, and data on the chemical compositions of these phases, have enabled us to estimate the approximate composition of the salt melt, which participated in the crystallization of apatite. For the most typical apatite:anhydrite ratios (60:40 - 30:70), the following range of compositions (wt %) [p. 1454] has been obtained: 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, 1.1-0.8 SrO, 0.3-0.2 Na_2O, and 0.2 H_2O; the density of the melt is 2.9 g/cm^3.

<u>Enclosing limestones and their xenoliths in alkaline rocks</u>. Owing to the necessity to consider the nature of the carbonatite inclusions or segregations petrographic and geochemical studies have been made on the limestones from the Paleozoic country rocks of the Mushugai-Huduk Complex (Table 4). Limestones have played a significant part in the make-up of these sequences [1]. They consist mainly of white chemogenic varieties, virtually completely

+ Компонент	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	0,99	0,97	1,01	25,09	20,13	0,29	0,90	1,15	0,83	1,15	24,64	22,71	0,89	24,37
TiO_2	0,02	0,04	0,04	0,04	0,03	0,02	0,03	0,05	0,03	0,02	0,02	0,03	0,04	0,03
Al_2O_3	0,14	0,13	0,15	0,06	0,88	0,05	0,16	0,15	0,40	0,59	0,94	0,84	0,31	0,90
Fe_2O_3	0,31	0,28	0,30	0,78	0,70	0,22	0,48	0,38	0,47	0,29	0,75	0,68	0,37	0,72
FeO	0,10	0,11	0,10	0,09	0,12	—	—	—	—	—	0,09	0,10	—	0,10
MnO	0,03	0,03	0,06	0,13	0,12	0,03	0,05	0,04	0,04	0,05	0,14	0,12	0,04	0,12
MgO	0,31	0,24	0,38	0,10	0,14	0,32	0,31	0,25	0,41	0,28	0,18	0,22	0,32	0,18
CaO	54,61	54,70	54,52	40,12	40,05	55,40	54,47	54,25	54,44	54,12	40,00	41,21	54,50	50,78
Na_2O	0,02	0,03	0,02	0,49	0,42	0,02	0,02	0,03	0,09	0,12	0,48	0,40	0,06	0,44
K_2O	0,05	0,07	0,04	0,08	0,08	0,02	0,04	0,07	0,10	0,13	0,05	0,05	0,08	0,06
P_2O_5	Не обн	0,01	Не обн	0,02	0,03	Не обн.	Не обн	Не обн.	Не обн.	Не обн.	0,07	0,02	Не обн.	0,03
CO_2	43,08	42,37	41,96	31,02	31,37	43,00	41,87	41,19	42,35	41,96	31,36	32,22	42,09	31,75
F	0,02	0,08	0,02	0,10	0,12	0,08	0,05	0,06	0,05	0,15	0,08	0,10	0,08	0,10
S	0,02	0,02	Не обн	Не обн	0,02	0,01	0,02	0,04	0,19	0,14	0,03	0,02	0,09	0,02
Sr	420	1400	380	970	1000	280	410	1300	1400	1300	240	760	1000	610
Ba	38	130	57	36	43	63	33	120	68	110	18	40	78	32
Pb	5	29	3,5	0,3	7,1	4,2	12	17	26	20	4,8	6,3	20	6
Zn	20	24	10	35	29	7,6	14	29	14	14	27	15	17	26
Zr	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Co	1	1	1	1	1	2	2	2	2	2	2	2	2	1
Ni	2	2	2	4,5	5,4	2	2	2	3,0	4,0	1,2	2,0	3	3
Cr	3	3	3	3	3	3	3	3	3,0	3,0	3	3	3	3
V	6	3	5	10	16	3	3	6	3	5	3	13	4	10
Cu	2,4	2,8	2,3	2,8	3,0	2,0	3,0	2,1	1,4	1,0	4,0	3,0	1,8	3,4
La	8,2	36	9,0	11	24	9,6	12	39	15	21	16	32	19	17
Ce	5,9	33	5,8	12	31	8,2	11	44	22	30	28	40	27	25
Nd	2,4	8	2,6	6,9	17	3,0	5,3	20	7	11	12	21	9	12
Yb	0,4	0,6	0,4	0,9	0,8	0,5	0,7	1,1	0,5	0,7	0,7	1,0	0,7	0,8
Y	5,0	8,5	5,3	16	18	5,8	8,0	19	6,3	8,0	7,0	18	6	10
n	9	2	1	2	1	1	1	1	1	1	1	1	4	2

Table 4. [p. 1455] Chemical Composition of Limestones and Their Xenoliths in the Alkaline Rocks, wt %

Notes. 1-5) limestones of surrounding sequences: 1-3) chemogenic: 1) average composition, 2) at contact with trachytes, 3) at 3 m from contact with trachytes; 4,5) organogenic: 4) average composition, 5) at contact with syenite-porphyries; 6-12) limestone xenoliths in alkaline rocks: 6-8) in trachytes (respectively from central to peripheral parts of xenolith), 9,10) in melanephelinitic tuffs (respectively inner and peripheral parts of xenolith), 11,12) in syenite-porphyries (respectively inner and peripheral parts of xenolith), 13.14) average compositions: 13) xenoliths of chemogenic limestones, 14) xenoliths of organogenic limestones.

\+ Component

++ Not found

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made up of calcite, and less commonly, gray organic varieties, also enriched in silica, and partly in alumina and alkalies.

All the limestone varieties are marked by low concentrations of virtually all the rare elements examined. At the contact with the alkaline rocks of the Mushugai-Huduk Complex, the limestones have usually been recrystallized, and the concentration of Sr, REE, and partly Ba, Pb, and Zn has increased somewhat, and the role of the light lanthanides has increased (Table 4). But the concentrations of these elements, as compared with that of the carbonatites in the limestones, remain low. The above-mentioned changes in the composition of the near-contact limestones may be traced over distances of not more than 1-2 m.

Limestone xenoliths (chemogenic in the trachytes and melanephelinitic tuffs and organogenic in the syenite-porphyries) have also been discovered in the alkaline rocks of the Mushugai-Huduk Complex. The dimensions of the xenoliths reach 6 x 14 cm. Their shape, as a rule, is angular or rounded-angular, and contacts with the alkaline rocks are sharp. A conformable trachytoid arrangement with the xenolith outlines has been identified in the trachytes. Recrystallization of the carbonate matter in the xenoliths is typical, and in the large clasts, it mainly affects their marginal parts with a width of not more than 5 cm. In spite of recrystallization, a banding has been preserved in the xenoliths, discordant with respect to the contacts with the alkaline rocks. Attention is drawn to the absence of signs of assimilation and skarning, specific to mineralized carbonatite inclusions, and seemingly partial melting or dissolution of the xenoliths. The xenoliths have inherited the principal petrochemical features of the limestones of the surrounding sequences and differ markedly [p. 1456] in their chemistry from the carbonatite inclusions (Table 2). In comparison with the surrounding limestones, the small xenoliths and the outer portions of the large xenoliths are somewhat enriched in Ba, Pb, Sr, and REE. But the cores of even small xenoliths (measuring more than 5-6 cm) are virtually indistinguishable geochemically from the unaltered limestones (Table 4). At the same time, the concentration of a number of rare elements in the recrystallized limestones, although marked, differ from that in the carbonatite segregations and carbonatites, which is richer by an order or more in Ba, Pb, REE, and Zr, and contains markedly more elements of the Fe and Cu group, and also Sr (on average by 15 times). Even the limestone xenoliths in the melanephelinitic pyroclastics, maximally enriched in Sr ($\leq 0.18\%$), contain almost five times less of it than do the carbonatite segregations from these same rocks ($\leq 1.02\%$). The difference in Sr concentration between the limestone xenoliths and the carbonatite segregations found in the syenite-porphyries, is even more significant.

DISCUSSION OF RESULTS

Origin of carbonatite inclusions. The above data indicate the endogenic nature of the carbonatite inclusions and their clear genetic connection with subalkaline magmatism. The mineralogical-petrographic data point to the generally synchronous formation of the magmatic rocks and the segregations. The carbonatite segregations are undoubtedly not limestone xenoliths, differing from the latter both in their geochemical indices (Table 4), and also in the morphology of the segregations which indicate the successive formation of the minerals in them from the outer towards the inner parts. The segregations are not normal late amygdales, typical of many volcanics (of calcite, agate, and other kinds). The minerals of the segregations are high-T forms and have crystallized from salt melts at T close to those of crystallization of the silicate magmas of the country rocks. An undoubted similarity has been recognized between the rare-earth composition of the segregations, the carbonatites, and the magmatic rocks of the complex (Table 1), especially clearly manifested in the contemporaneous enrichment of these rocks in volatile components, Sr, Ba, Zr, Pb, Zn, V, REE, light lanthanides vis-a-vis heavy ones and Y ($La/Yb > 68$). In geochemical respects, the segregations seem to be the equivalents of carbonatites, genetically associated with a relatively potassic alkaline magmatism [2]. Moreover, the isotope data (Table 5) indicate a single mantle source of material for the alkaline rocks, carbonatites, and carbonatite segregations of the Mushugai-Huduk Complex. The P Sr-isotope ratio in these formations is respectively 0.7045-0.7063; 0.7048-0.7055; and 0.7049-0.7062, that is, it falls virtually within one interval. At the same time, this ratio in the limestone xenoliths, even those maximally enriched in juvenile Sr, does not fall below 0.7063. It is typical that the last value has been obtained for a limestone xenolith in melanephelinitic tuffs, the carbonatite inclusions in which have a $^{87}Sr/^{86}Sr$ values of 0.7053. On the whole, the Sr-isotope composition in the xenoliths is comparable with that in the limestones of the country rocks, which have been recrystallized and enriched in endogenic Sr at the contacts with the rocks of the alkaline complex.

The results of the geological, mineralogical-petrographic, and geochemical studies do not suggest any marked involvement of carbonate sedimentary material in the formation of the carbonatites and carbonatite segregations. This is indicated by the insignificant scale of transformation of the limestones and even the xenoliths, not only at the contacts with the alkaline volcanics, but also with the deeper-seated syenite-porphyries. Transformations have been expressed only in recrystallization of the limestones without any traces of their dissolution or skarning. It is [p. 1457] remarkable that although the recrystallized limestones and their xenoliths at their contacts with the alkaline rocks, as compared with the unaltered sedimentary rocks, have been substantially enriched in a number of rare elements, the levels of amounts of the latter, including Sr, differ considerably from those in the carbonatite segregations.

Table 5. [p. 1457] Sr-Isotope Composition in Various Formations in the Mushugai-Hudak Complex

Spec. No.	Sample No.	Formation	^{87}Sr/^{86}Sr
1	1897	Melanephelinite	0.7057
2	1/1	"	0.7045
3	1874	Trachyte	0.7057
4	1882	Syenite	0.7058
5	12/16	Syenite-porphyry	0.7063
6	1877	Carbonatite	0.7054
7	27/2	"	0.7048
8	62/2	"	0.7055
9	1/1a	Carbonatite segregation in melanephelinitic tuff	0.7053
10	1/15a	The same in melanephelinites	0.7054
11	1/17	" "	0.7054
12	12/16a	Carbonatite inclusion in syenite-porphyries	0.7049
13	69/1	The same in trachytes	0.7062
14	62/7	Limestone	0.7086
15	1897/5	"	0.7082
16	1897/7	The same at contact with carbonatite (Sample 1877)	0.7070
17	62/5	The same (Sample 62/2)	0.7081
18	68/3	Limestone xenolith in trachytes	0.7071
19	70/4b	The same in melanephelinitic tuffs	0.7063
20	1	Apatite rock	0.7055
21	1905	"	0.7052

Notes. Analyses of samples 1, 3, 4, 6, 7, 14, 15, 20, and 21 carried out in Institute of Earth's Crust of Siberian Division of Academy of Sciences of the USSR [1], and remainder in the Vinogradov [sic; ? Vernadsky. DAB] Institute of Geochemistry.

Two variants of the genetic interpretation of the relations between the carbonatite segregations examined and alkaline silicate rocks are possible: 1) immiscibility of silicate and carbonatite melts, and 2) formation of carbonatite segregations from fluid in cavities of cooled silicate rocks. The factual data agree with the first variant, according to the following considerations. P microinclusions of salt melts have been discovered in carbonatite segregations in the melanocratic alkaline volcanics, as already recorded; these melts were homogenized at 1090-1200°C, which is extremely close to the Ths of inclusions of melanephelinitic melt in pyroxene phenocrysts from the same volcanics (1190-1200°C) [8]. It is typical that the solid inclusions, present in the fluorite examined, along with calcite also consist of pyroxene, fluorite, and apatite, that is, mineral-phenocrysts of the enclosing melanephelinites. In all probability, the high-T salt melts, from which the carbonatite segregations were formed, separated by liquation from a silicate magma, already containing many of the same mineral-phenocrysts.

The composition of the microinclusions in the fluorite from the carbonatite segregations permits us to assess the main features of the chemical composition of such liquids, coexisting with silicate magmas. The compositions of the salt melts, from which the carbonatites were formed, have been based on the fluorite component, in which minor silicate and carbonate components, enriched in sulfur, have been dissolved. At the same time, calcium carbonate (on average, 2/3 of the volume) has played a predominant role in the composition of these same segregations, although enrichment in fluorine and sulfate sulfur has also been recorded. [p. 1458] The amount of fluorine concentrated in the fluorite in the various kinds of segregations, amounts to 3.35-12.58 wt %, and the amount of sulfate sulfur may reach 4.68 wt %. The difference between the composition of the salt melts from the microinclusions and that of the segregations themselves indicates the marked loss of many components (especially F and S) during crystallization of these melts. Judging by the carbonate enrichment of the central portions of the segregations, crystallization of the salt melts took place by fractionation with the enrichment of the residual melt in carbonate, whereas fluorite and silicates had crystallized earlier on.

Definite differences have been identified in the composition of the carbonatite segregations formed from salt melts that had separated from melanephelinitic and syenitic (trachytic) magmas. Carbonatite segregations of the latter kind are markedly poorer in F, but richer in sulfate S, Ba, Pb, and REE, K relatively to Na, and light lanthanides relatively to heavy ones and Y. The K_2O/Na_2O ratio in them ranges from 2.8 to 3.1; and La/Yb >330, whereas these values in the carbonatite segregations, associated with the melanephelinitic magma, are respectively lower than 0.7 and 300 (Table 2).

Differences in REE, Ba, Zn, and Pb distribution between the carbonatite segregations and the alkaline magma have been especially clearly marked. Whereas the distribution coefficients of these elements in the melanephelinitic magma are less than unity, they are greater than this in the case of a magma of syenitic (trachytic) composition. Consequently, the Sr-distribution coefficient, which is always greater than unity, and also those of Co and V, also increases. At the same time, during passage towards a syenitic (trachytic) melt, the distribution coefficients of Ni, Cr, and Zr, which are always less than unity, markedly decrease.

Origin of apatite segregations. The geological and geochemical data on all counts indicate the genetic unity of the apatite-bearing and subalkaline rocks of the Mushugai-Huduk Complex, which has also been confirmed by the results of a Sr-isotope study on these rocks (Table 5), indicating a single mantle source of their material. Moreover, the geological and petrographic data suggest the closeness in time of or even synchroneity in the formation of the apatite-bearing rocks and their enclosing syenite-porphyries. It is impossible to regard the former as relicts of hypothetical phosphate rocks, metamorphosed at the contact with an alkaline intrusion and impregnated with alkaline magma, because in the contact syenite-porphyries, cross-cutting apatite veinlets have been recorded, and in the apatite streaks, a zoned crystal of alkali-feldspar (the equivalent of the phenocrysts in the syenite-porphyries) has been found, impregnated with enclosing apatite. We may also scarcely speak about the superimposition of a later apatitization, and the development of apatite metacrysts in the already-formed syenite-porphyries, because there have been no geological or petrographic traces of this phenomenon.

In the footwall of the syenite-porphyry stock, there are true apatite streaks, that is, isolated aggregates of apatite crystals, which are evidently also models of the capacity to form large bodies of anchimonomineralic rocks, and no alterations have been identified at the contact with such streaks in the syenite-porphyries (Table 2). A similar picture has also been observed in rocks with predominant apatite, especially the feldspar-apatite varieties, in which a medium-grained syenitic mass (the equivalent of the groundmass of the syenite-porphyries) seemingly cements the latter, without traces of interaction with the apatite component. The zonation revealed in the structure of the apatite-bearing rocks is not metasomatic. It, as follows from the mineralogical-petrographic data and from a study of the chemical composition of the rocks, has been controlled exclusively by a change in the ratio of the apatite and syenite components.

In order to understand the origin of such streaks, the discovery in the apatite of P salt-melt inclusions of apatite-bearing rocks with a Th = 1240-1290°C, [p. 1459] which is very close to the Tf of the syenites (trachytes) of the Mushugai-Huduk Complex, is very important [8]. The closeness in the T of the silicate and salt melts, identified from the microinclusions, also derives from the petrographic observations. In the apatite segregations, there are impressions of the groundmass of the syenite-porphyries, which in the feldspar-apatite and essentially apatite rocks is always xenomorphic with respect to apatite and contains no phenocrysts, seemingly cementing individual crystals of this mineral and their aggregates or being located in the interstices between the latter. This suggests that the Tcs of the salt phosphate-sulfate melt and the groundmass of the syenite-porphyries were similar.

The salt melt in this case has an essentially phosphate-sulfate composition, is enriched in volatiles (mainly F and S), and is anomalously enriched in REE, amongst which there is a marked prevalence of light lanthanides. This melt contains a certain number of other petrogenic elements, and also Sr and Ba, which enter the composition of the apatite and the syngenetic phlogopite. The phosphate-sulfate melt, evidently precipitated from the syenitic magma, is markedly enriched, as compared with the later in Ca, P, S, rare earths, and also Sr. The amounts of Ba and the value of δEu in the phosphate segregations and the syenite-porphyries, seem to be similar.

CONCLUSIONS

1. In the melanephelinites, trachytes, and porphyritic syenites, carbonatite and apatite steak-like segregations have been revealed, syngenetic and closely synchronous with the formation of the enclosing magmatic silicate rocks.

2. In overall chemical composition, distribution of rare elements, and Sr-isotope composition, the carbonatite segregations differ markedly from the xenoliths of the enclosing carbonate rocks, and are similar to the vein and stockwork bodies of the rare-earth carbonatites in the Mushugai-Huduk Complex.

3. The carbonatite segregations were formed during crystallization of a high-T (~1200°C) salt (rich in the fluorite component) dry melt, whereas the segregations of apatite rocks were formed during crystallization of such a high-T phosphate-sulfate salt melt, enriched in REE. The process of crystallization of these salt melts has led to significant enrichment of the residual liquids in carbonates, which are the principal components of the carbonatites.

4. These data suggest that immiscibility (liquation) of the silicate and salt melts has played an important role in the formation of the rocks of the Mushugai-Huduk Complex.

REFERENCES

1. Samoilov, V.S. & V.I. Kovalenko, 1983, The Assemblages of Alkaline Rocks and Carbonatites of Mongolia: Nauka Press, Moscow, 196 pp [in Russian].
2. Samoilov, V.S., 1984, The Geochemistry of the Carbonatites: Nauka Press, Moscow, 190 pp [in Russian].
3. Romanchev, B.P. & S.V. Sokolov, 19798, Geokhimiya, no. 2, p. 229.
4. Rankin, A.H. & M.J. LeBas, 1974, Nature, Lond., v. 250, no. 5463, p. 206.
5. LeBas, M.J., 1981, Mineralog. Mag., v. 44, p. 133.
6. Philpotts, A.R., 1967, Econ. Geol., v. 62, no. 3, p. 303.
7. Brandt, S.B. et al., 1981, Dokl. Akad. Nauk SSSR, v. 260, no. 2, p. 466.
8. Naumov, V.B. et al., 1986, Dokl. Akad. Nauk SSSR, v. 288, no. 2, p. 453

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Received by Editor
May 4, 1987

Indices

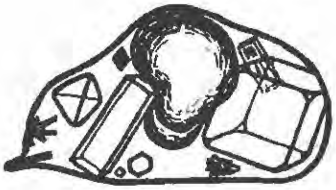
The user should keep in mind the following features of these indices. The indexing procedures and entries are continuously evolving and hence are not uniform from one volume of Fluid Inclusion Research to the next, and even within a given volume consistency cannot be claimed. In some entries, only the 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 subject heading even though the index word does not occur in the abstract. The deposit type is indexed only where it is evident without research. 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 possible 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. 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. Entries that would include too many page references are listed without page numbers. Some entries with broad and diffuse applicability (e.g., "Geobarometry, methods and comparisons") have only a few of the most pertinent page references.

LOCALITY INDEX

Notes: See page 485. 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 original transliteration; various transliteration procedures yield different spellings: Began and Began'skii, Blyava and Blyavinsk, Kochkar and Kochkarskoje, Volhynia and Volyn, Kirin and Jilin.



Errata

Note: This errata section includes corrections to any published volume, but does not reproduce errata published earlier. The editors would appreciate notice of any other errors or omissions. In particular, we would appreciate corrections of citations which have been erroneously entered under the given name rather than the family name.

TEXT

Volume	Page	Item+	Line*	
17	356	2	11	Change Kiling to Kilinc
17	363	4	7	Change Blagsdat' to Blagodat'
18	220	3	2	Change Strzogom to Strzegom
18	265	4	2	Change Protezn to Polezn
19	225	3	1	Change to Kolpakova N.N. and Manucharyants, B.O.
19	478	4		Move Wong et al. to p. 477 and insert as item 2
20	34	3	3	Change to p. 757-762
20	70	4	-10	Change to Norman and Landis
20	131	2	1	Change to McLaren
20	131	2	4	Change to "Australian Natl. Univ."
20	207	1	-3	Change to "common"
21	17	2	8	Change to read: p. 16-17
21	197	2	1	Change Konevchuk to Gonevchuk
21	275	2	1	Change Noisik to Nosik and move to p. 276
21	319	5	7-8	Change to Vol. 19, p. 360-361, under Reyf.

INDICES

18	484	Under "Daughter minerals," "Biotite" is out of alphabetical order
19	525	Under "Iodine", change p. 138 to p. 139
19	538	Under "Bushveld complex", delete p. 381
20	535	Under "Decrepitate analysis", add p. 40

+Partial items are also counted.
*Minus refers to lines up from end of item.

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CITATION EQUIVALENTS IN VOL. 21

The following Russian citations in Vol. 21 were found, after preparation of photo-ready copy, to be equivalent or essentially equivalent to abstracts in previous volumes as listed (in part with different titles and/or author sequence or transliteration).

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31	2	19	39	3	
107	3	18	465	3	Under Yefimova et al.
112	1	19	130	2	Under Fayziyev et al.
119	3	19	140	3	
135	1	19	158	4	
172	2	19	190	3	Under Ikorskiy
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197	7	19	225	3	Under Kolpakova and Manucharyants
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275	2	19	315	4	Under Nosik and Serova
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354	5	19	222	2	Under Kogarko et al.
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384	2	19	428	3	

ISBN 0-472-02021-8

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